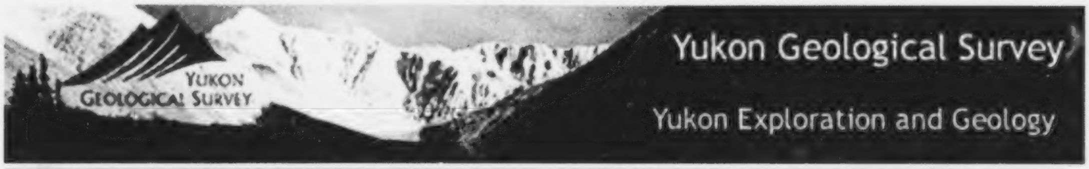

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Yukon Exploration and Geology 1998

Edited by C.F. Roots and D.S Emond

A volume dedicated to Bruce Nesbitt

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MINERAL INDUSTRY

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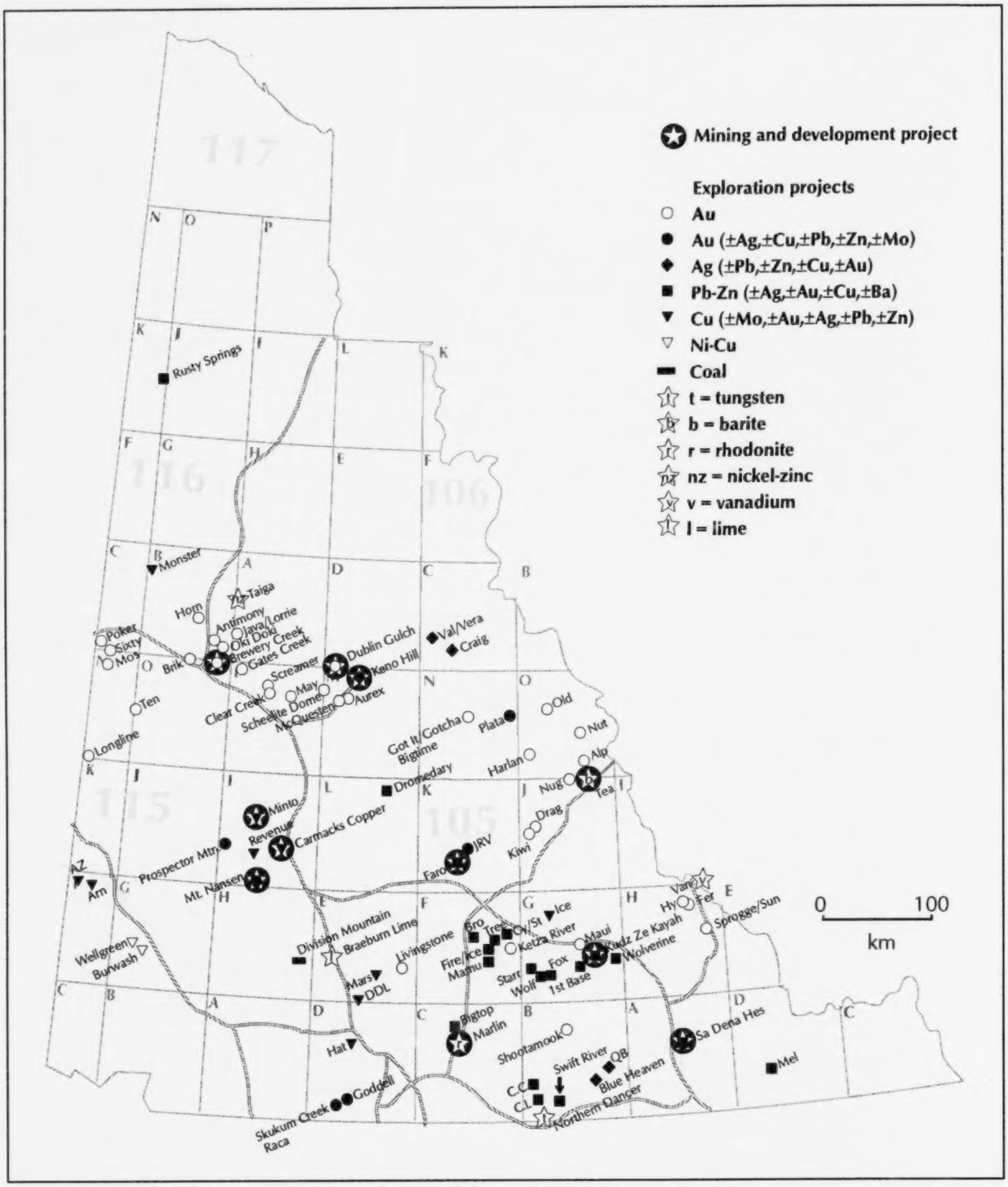
Mining and development project
Exploration projects
○ Au
● Au (±Ag,±Cu,±Pb,±Zn,±Mo)
◆ Ag (±Pb,±Zn,±Cu,±Au)
■ Pb-Zn (±Ag,±Au,±Cu,±Ba)
▼ Cu (±Mo,±Au,±Ag,±Pb,±Zn)
▽ Ni-Cu
▬ Coal
t = tungsten
b = barite
r = rhodonite
nz = nickel-zinc
v = vanadium
l = lime
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117
116
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105
Rusty Springs
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Taiga
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Oki Doki
Brewery Creek
Gates Creek
Poker
Sixty
Mos
Brik
Dublin Gulch
Keno Hill
Val/Vera
Craig
Screamer
May
Clear Creek
Scheelite Dome
McQuesten
Aurex
Ten
Longline
Got It/Gotcha
Bigtime
Plata
Old
Nut
Harlan
Alp
Nug
Tea
Dromedary
Minto
Revenue
Carmacks Copper
Prospector Mtn
Mt. Nansen
Faro
JRV
Drag
Kiwi
AZ
Am
Wellgreen
Burwash
Division Mountain
Braeburn Lime
Livingstone
Mars
DDL
Bro
Tree
Oy/St
Ice
Ketza River
Fire/Ice
Mamu
Maui
Kudz Ze Kayah
Wolverine
Start
Wolf
Fox
1st Base
Van
Hy
Fer
Sprogge/Sun
Bigtop
Martin
Hat
Shootamook
Sa Dena Hes
Mel
Swift River
QB
Blue Heaven
C.C.
C.L.
Northern Dancer
Skukum Creek
Goddell
Raca

Figure 1. Location of active Yukon mines and exploration projects in 1998. Not all projects (particularly reconnaissance) are shown on the map. NTS grid in background.

YUKON MINING AND EXPLORATION OVERVIEW – 1998

Mike Burke
Yukon Geology Program

Burke, M., 1999. Yukon mining and exploration overview – 1998. *In:* Yukon Exploration and Geology 1998, C.F. Roots and D.S. Emond (eds.), Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 2-30.

RÉSUMÉ

En 1998, le Yukon (Fig. 1) a été l'objet de nombreux travaux de reconnaissance axés sur les potentialités aurifères de la suite intrusive de Tombstone du Crétacé moyen et de celles d'autres suites intrusives du Crétacé. Les principaux modèles de gisements recherchés étaient ceux de type Fort Knox, True North, Brewery Creek, Carlin et Pogo. L'exploration aurifère a représentée plus de 60 % des coûts d'exploration, qui se sont chiffrés à quelque 15,4 millions de dollars en 1998 (Fig. 2). La baisse des dépenses d'exploration se reflète dans le nombre de projets d'exploration d'un niveau avancé (ceux impliquant des forages au diamant) qui a chuté de 80 % depuis 1997. En 1998, l'exploration des métaux communs avait pour cible plusieurs styles de gisements. Les amas de sulfures massifs volcanogènes (SMV) ont encore été le point de mire de nombreux programmes d'exploration, notamment du vaste programme de forages au diamant, exécuté par Atna Resources, qui a permis de prolonger le gisement Wolf (découvert en 1997). Les gisements de cuivre et de zinc à haute teneur en argent ont également fait l'objet d'exploration par Manson Creek Resources à l'est de Keno et par Nordac Resources dans le sud du Yukon, à proximité de Rancheria. Bien que l'exploration des SMV dans le district de Finlayson Lake ait subi une forte baisse par rapport aux dernières années, plusieurs programmes y ont été réalisés, dont les forages au diamant effectués par Cominco sur sa propriété de Kudz Ze Kayah.

En tout, 5148 concessions minières ont été jalonnées en 1998 (Fig. 3). Ce chiffre est inférieur à celui des années précédentes. Toutefois, le plus grand nombre de jalonnements (75%) a été réalisé dans les districts miniers de Dawson et de Mayo. Ce pourcentage indique le nombre de nouvelles propriétés jalonnées à la suite de la mise en oeuvre de nombreux programmes de reconnaissance pour l'or dans ces régions. Le nombre de concessions minières en règle a chuté de 66 287, par rapport à l'année précédente; mais il reste plus élevé que la moyenne (Fig. 4).

Les deux mines d'or en exploitation au Yukon, Brewery Creek et Mount Nansen, ont continué leur production; la production du gisement de barytine Tea et du gisement de rhodonite Marlin a été faible. Viceroy Resources ltée prévoit que la production de la mine Brewery Creek atteindra 2572 kg (80 000 onces) d'or en 1998, à un coût au comptant de 180 $US. À la fin du troisième trimestre, la production d'or était de 1637 kg (52 638 onces) à un coût au comptant de 197 $US. Brewery Creek a démontré pendant trois hivers consécutifs que l'on pouvait utiliser la lixiviation en tas, peu coûteuse, avec efficacité au Yukon. La mine Mount Nansen de BYG Resources a produit 472 kg (15 190 onces) d'or et 1208 kg (38 849 onces) d'argent à partir de son exploitation à ciel ouvert Brown-McDade.

Les coûts de mise en valeur concernent principalement le gisement de cuivre-or-argent Minto où on a construit la semelle de fondation de l'usine de traitement, un écran d'injection sur la digue à stériles et un camp permanent ont été terminés en vue de la construction définitive en 1999. Les exploitations minières du Yukon ont engagé également des dépenses de mise en valeur, principalement la mine Brewery Creek où on a exécuté des forages intercalaires et des essais en colonne, agrandi l'aire de lixiviation en tas et ajouté une étape intermédiaire de lixiviation. Au total, les coûts de mise en valeur au Yukon se sont élevés à environ 6,0 millions de dollars.

INTRODUCTION

Yukon (Fig. 1) experienced a large number of reconnaissance-style exploration projects in 1998 directed at the gold potential of the mid-Cretaceous Tombstone suite intrusive belt, as well as that of other Yukon Cretaceous intrusive suites. Fort Knox, True North, Brewery Creek, Carlin and Pogo -style deposits were the main mineral deposit models utilized. Gold exploration accounted for more than 60% of exploration expenditures which totaled approximately $15.4 million (Fig. 2) in 1998. Production in 1998 continued from the Yukon's two operating gold mines, Brewery Creek and Mount Nansen, as well as minor production from the Tea barite deposit and the Marlin rhodonite deposit. Unfortunately, production from the Faro Pb-Zn-Ag mine was suspended in January, 1998 when the Anvil Range Mining Corporation filed for court protection in order to restructure the company. Mine development expenditures of approximately $6.0 million were incurred at the presently operating mines, and in the development of the Yukon's next mine, the Minto Cu-Au-Ag project.

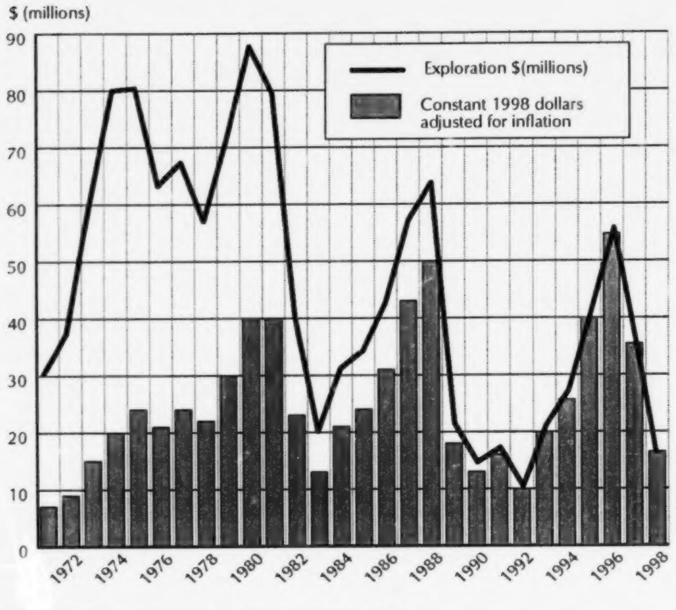


Figure 2. *Exploration expenditures: 1971-1998.*

The decrease in exploration expenditures from 1997 ($35 million) is reflected in the number of advanced exploration projects involving drilling. The approximately 20,000 metres diamond drilled in 1998 was down 80% from 1997 totals. Base metal exploration in 1998 was directed at several styles of deposits. Volcanogenic massive sulphide (VMS) deposits continued to be the focus of numerous programs, including a major diamond drilling program by Atna Resources resulting in the expansion of the Wolf deposit (discovered in 1997). Lead and zinc deposits with high silver contents were also explored east of Keno City in central Yukon by Manson Creek Resources, and in southern Yukon near Rancheria by Nordac Resources. Exploration for VMS deposits in the Finlayson Lake district declined drastically in relation to recent years. Among the few programs conducted in the region was diamond drilling by Cominco on their Kudz Ze Kayah property.

The number of quartz claims staked to the end of October, 1998 was 5148 (Fig. 3). This is lower than in previous years, however the bulk (75%) of

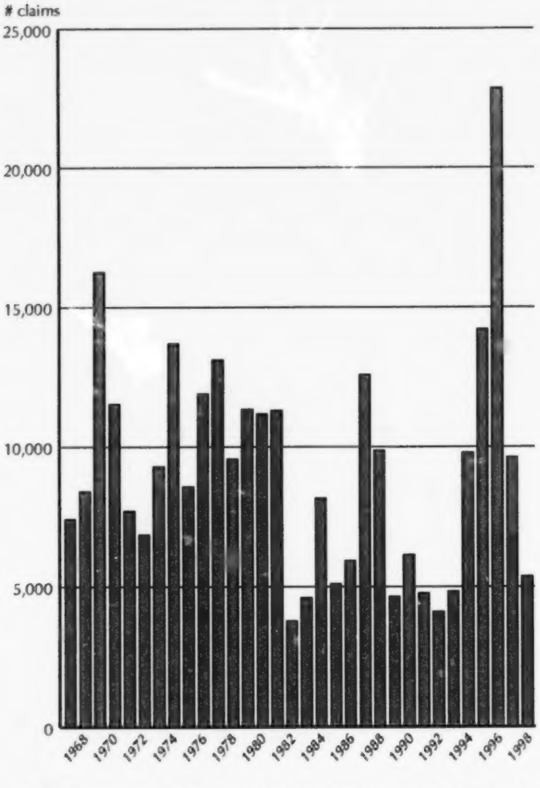


Figure 3. *Quartz claims staked: 1967-1998 (to end of October)*

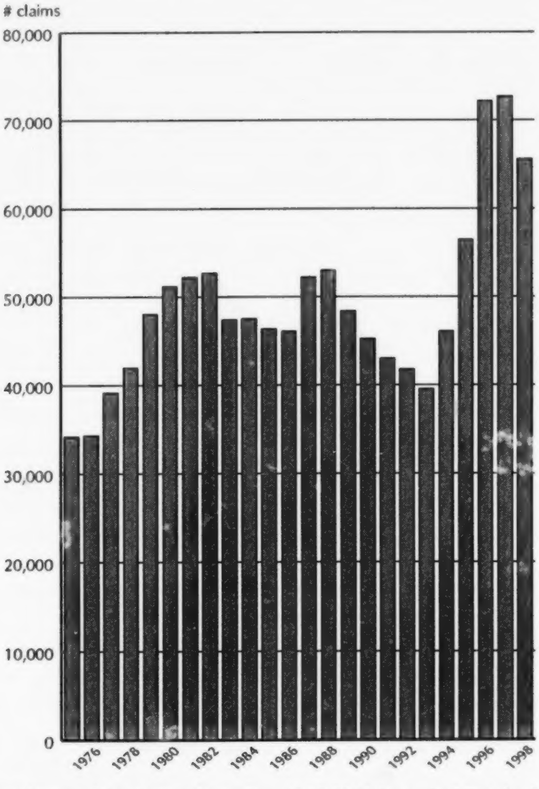


Figure 4. *Quartz claims in good standing: 1975-1998 (to end of October)*

staking was conducted within the Tombstone Intrusive Belt in the Dawson and Mayo mining districts. This reflects a number of new properties staked based on the numerous gold reconnaissance programs conducted in these areas. Claims in good standing have dropped to 66,287 (Fig. 4) which is down from 1997, but remains at levels higher than average.

MINING

Production continued at the Yukon's two operating gold mines, **Brewery Creek** (Yukon Minfile 116B 160) and **Mount Nansen** (Yukon Minfile 115I 064, 065). Minor production of 3000 tonnes was achieved from the **Tea** barite deposit (Yukon Minfile 105O 020) and 35 tonnes from the **Marlin** rhodonite deposit (Yukon Minfile 105C 017).

Viceroy Resources, Ltd., forecast 1998 production of 2572 kilograms (80,000 ounces) of gold from the **Brewery Creek** mine at a cash cost of US$180. Production to the end of the third quarter in 1998 was 1637 kilograms (52,638 ounces) gold at a cash cost of US$197. Proven and probable reserves at Brewery Creek were 13,317,000 tonnes grading 1.44 g/t Au as of December 31, 1997. Ore was mined principally from the Kokanee and Golden zones (Fig. 5) in 1998 with 2.238 million tonnes of ore delivered to the heap leach pad by the end of the third quarter. Waste mined to the end of the third quarter totaled 3.472 million tonnes. Viceroy also conducted extensive infill drilling on several zones within the reserve trend in order to upgrade geological resources to reserves (Diment and Craig, this volume). Significant expenditures were incurred in the expansion of the heap leach pad, column testing and in the addition of an intermediate leaching circuit. The intermediate

Figure 5. *The Golden pit at the Brewery Creek mine.*

leaching circuit effectively doubles the amount of ore under leach, resulting in increased gold production. Continued success at the Brewery Creek mine has proven for the third winter in a row that low-cost heap leaching can be used effectively in the Yukon.

In 1998, BYG Resource's **Mount Nansen** mine processed 136,095 tonnes of ore at an average head grade of 5.03 g/t Au and 43.25 g/t Ag; this production was from the Brown-McDade open pit (Fig. 6), yielding 472 kilograms (15,190 ounces) of gold and 1208 kilograms (38,849 ounces) of silver. A water balance problem in the tailings pond at the beginning of the year resulted in a shutdown and reduced milling rate; consequently, milling for the year has been at 50% capacity. Installation and commissioning of a water treatment plant has rectified the water balance problem and milling has continued at full capacity since June (700 tonnes per day). Mining to the end of September resulted in the removal of 151,763 tonnes of ore from the open pit. During this time, 513,165 tonnes of waste were removed including an 80,000 tonne push-back of the pit wall for the phase III mine design. A preliminary mine design for an open pit on the Flex deposit indicates a resource of approximately 82,000 tonnes grading 7.4 g/t Au and 312.5 g/t Ag. The Flex Zone is slated for production upon completion of permitting, bulk sampling and final feasibility. Production from the Brown-McDade pit is expected to be completed early in 1999. The discovery in the pit of a sulphide-rich breccia pipe, separate from the Main vein, represents a bulk tonnage underground target that may extend the mine life (Stroshein, this volume).

The **Tea barite deposit** is located near MacMillan Pass northeast of Ross River. H. Coyne and Sons of Whitehorse mined approximately 3000 tonnes of barite and processed it in their mill in Ross River. The barite was then shipped to Alaska for use as drilling mud in oil exploration on the North Slope.

Figure 6. *Robert Stroshein with BYG Natural Resources in the Brown-McDade pit.*

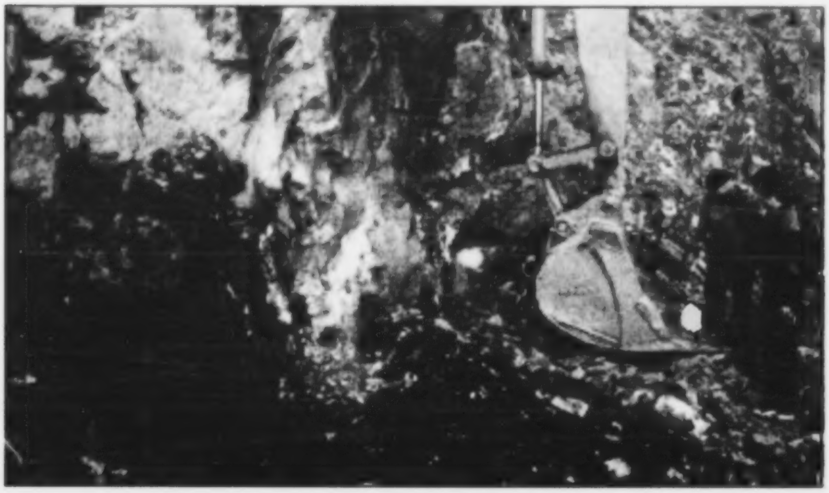


Figure 7. The lighter coloured areas in the photo are deep pink to red, high quality rhodonite at the Marlin deposit. This is unfortunately not as dramatic in black and white.

Sidrock (officially 12633 Yukon Inc.) produced 35 tonnes of high-quality rhodonite (Fig. 7) from the **Marlin** deposit in south central Yukon. The rhodonite was shipped to Vancouver and is being marketed to carvers in the Orient. Several of the larger pieces are being made into free form sculpture by Sidrock in Whitehorse and are destined for private collections and auction houses in San Francisco and New York. The deposit is believed to have formed as a stratiform synsedimentary manganese deposit hosted by the Big Salmon Metamorphic complex; later metamorphism developed the rhodonite-bearing skarn. Elsewhere on the property, bornite and chalcopyrite in a quartz-carbonate lens 0.3 m thick is exposed for a length of 10 m. The lens follows the foliation in quartz-biotite schist and gneiss of Mississippian(?) age, indicating the potential for other styles of mineralization (VMS) on this property.

MINE DEVELOPMENT

Mine development expenditures were incurred mainly at the **Minto** (Yukon Minfile 115I 021, 022) copper-gold-silver porphyry deposit where mill footings (Fig. 8), tailings dam

Figure 8. Jim Prock (foreground) of Minto Explorations explains construction of the mill of the Minto Cu-Au-Ag project to Hugh Copland (facing camera).

grout curtain and the installation of a permanent camp were completed in preparation for final construction in 1999. The mine is located on the west side of the Yukon River in central Yukon (Fig. 1). The current mine design calls for an open pit containing 6.51 million tonnes grading 2.13% Cu, 0.62 g/t Au and 9.3 g/t Ag at a stripping ratio of 4.9:1.0. The mill is designed for a throughput of 477,000 tonnes of ore per year, resulting in an initial mine life of 13 years. Development at the Minto deposit is being funded by Asarco who may earn a 70% interest in the property by funding the project to production. Minto Explorations retains 30% and is the operator of the project.

Development costs were also incurred at the Yukon's operating mines. At Brewery Creek, infill drilling, column testing, heap leach pad expansion and the addition of an intermediate leaching stage contributed to overall mine development expenditures. Development expenditures in the Yukon totaled approximately $6.0 million, and include the costs incurred in care-and-maintenance of existing mines, as well as the costs associated with permitting.

Cominco's **Sa Dena Hes** Zn-Pb-Ag mine (Yukon Minfile 105A 012, 013) and the **Keno Hill** Ag-Pb-Zn mine (Yukon Minfile 105M 001) of United Keno Hill Mines Limited remained on care- and-maintenance during 1998, awaiting an increase in metal prices which may trigger the resumption of production at these deposits.

Three projects remained in the permitting process in 1998. New Millenium Mining Ltd. continued with the comprehensive review of the **Dublin Gulch** Au deposit (Yukon Minfile 106D 021-029) under the Canadian Environmental Assessment Act. Dublin Gulch, an intrusive-hosted gold deposit, contains open-pit mineable reserves of 50.4 million tonnes grading 0.93 g/t Au. The **Carmacks Copper** deposit (Yukon Minfile 115I 008) is an oxidized Cu-Au porphyry deposit containing 14.1 million tonnes grading 1.01% Cu and 0.51 g/t Au. In 1998, Western Copper Holdings Limited continued their review of the Carmacks Copper project under the Environmental Assessment and Review Process. The **Kudz Ze Kayah** (Yukon Minfile 105G 117) deposit of Cominco awaits final signature on their Class A Yukon Water Licence. No production decision has been made on the VMS deposit which hosts open-pit mineable reserves of 11 million tonnes grading 5.9% Zn, 0.9% Cu, 1.5% Pb, 130 g/t Ag and 1.3 g/t Au.

GOLD EXPLORATION

For the first time in many years, exploration expenditures for gold surpassed expenditures for base metals in the Yukon. Recent exploration successes in Alaska related to mid-Cretaceous intrusive rocks, namely the Fort Knox and more recently the Pogo gold deposit, has boosted exploration in Yukon areas hosting similar geology to the Alaskan discoveries. The potential in the Yukon for similar plutonic-related deposits to these Alaskan discoveries has long been known and was illustrated by the discovery in 1991 of the Dublin Gulch gold deposit near Mayo, the closest known match to the Fort Knox model. The plutonic-related, low-cost, heap-leach Brewery Creek gold mine near Dawson has proven that these types of deposits can be economically exploited in the Yukon. Several senior mining companies conducted reconnaissance exploration programs (Fig. 9) in the mid-Cretaceous Tombstone belt, which resulted in the staking of several new properties. Other properties staked in previous years in this belt had exploration programs ranging from prospecting to diamond drilling.

Figure 9. *Local helicopter companies were pleased with the large amount of reconnaissance programs conducted in 1998.*

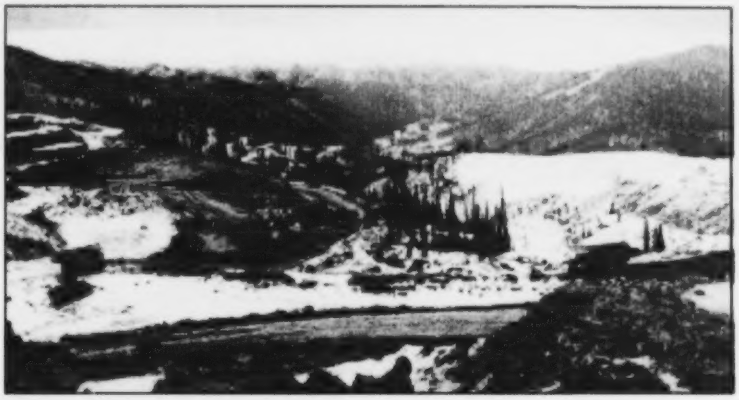


Figure 10. Two of the main zones of exploration, the Lucky (background left) and Bohemian (background right) at the Brewery Creek mine. The Golden Pit is in the foreground.

Viceroy Resources, Ltd. conducted extensive exploration on several mineralized zones on the **Brewery Creek** mine property (Yukon Minfile 116B 160). Mineralization at Brewery Creek is hosted in oxidized mid-Cretaceous Tombstone Suite quartz-monzonite sills and underlying Devono-Mississippian greywacke of the Earn Group. Exploration at the Brewery Creek mine property in 1998 placed an emphasis on moving ounces of gold from the resource to the reserve category, as well as delineating new oxide resources adjacent to existing reserves (Diment and Craig, this volume). Reverse circulation drilling focused on expanding oxide resources at the Lucky, Bohemian (Fig. 10), East Big Rock, Moosehead, Pacific, Golden and Blue zones. Trenching and road building also started in the South Canadian and Sleemans targets. Exploration at the Bohemian Zone, which had a resource of 364,000 tonnes grading 0.99 g/t Au (as of December 31, 1997), was very successful with drilling intercepts such as 1.2 g/t Au over 40 metres, 2.18 g/t Au over 14 metres, and one of the best holes on the property drilled to date returning 4.42 g/t Au over 46 metres. This resource was upgraded to 1.3 million tonnes grading 1.6 g/t Au as of July, 1998 and the resource will soon be updated based on additional drilling. Preliminary results from other exploration on the property included trenching in the Schooner Zone which returned 1.27 g/t gold over 66 metres, and 0.92 g/t gold over 12 metres from the South Golden Zone. Results from the extensive exploration program of 1998 were still being compiled and interpreted at year-end and announcements relating to the exploration at the mine site should be available in the first quarter of 1999. Viceroy also conducted exploration immediately south of Brewery Creek on the Gates Creek project which is located on Class A lands optioned from the Tr'ondek Hwech'in First Nation.

Viceroy followed up on extensive reconnaissance exploration programs conducted in 1997 and continued with additional reconnaissance programs in 1998. Gold mineralization related to the mid-Cretaceous Tombstone and Tungsten intrusive suites were targeted. In the 1998 season, the company staked several properties and conducted first phase exploration programs involving silt and soil sampling, prospecting and mapping. Follow-up work on a brand new discovery, the **Harlan** property (NTS 105O/4, 5), has defined a breccia zone within a chert pebble conglomerate with anomalous gold values up to 7.4 g/t. The zone is approximately one kilometre wide and five kilometres long. The breccia zone is bounded by a thrust fault which juxtaposes a thick section of fine sediments intruded by limonitic quartz monzonite sills up to 30 metres thick with gold values up to 2 g/t. Results from the numerous projects of Viceroy Resources are being compiled.

International Kodiak Resources Inc. explored the large **Oki Doki** property (NTS 116B/1, A/4) which borders the Brewery Creek mine to the north and east. A program of silt and soil geochemistry (Fig. 11), prospecting, rock sampling and geological mapping followed by Induced Polarization (IP) geophysical surveys was conducted during the 1998 field season. Grid-based soil geochemistry in the area immediately north of the Brewery Creek

Figure 11. Portable auger drills were used to collect soil samples on the Oki Doki property near Brewery Creek.

mine property identified an anomalous area 1500 metres in length by 100 to 300 metres wide, with up to 646 ppb Au, 392 ppm As, 593 ppm Sb, and 2235 ppm Hg. The anomalous area trends east-west similar to the reserve trend at Brewery Creek. Preliminary IP results from surveys over the anomalous area showed chargeability anomalies with coincident to flanking resistivity features. For 1999, excavator trenching and diamond drilling is planned to test these areas. A similar program to the east identified narrow semi-massive to massive arsenopyrite in fractures within a large, roughly east-northeast trending shear zone near the margin of the Mike Lake intrusive. Select grab sampling of the mineralization yielded values up to 125 g/t Au.

Homestake Canada optioned from Tombstone Explorations the **Lorrie** property (Yukon Minfile 116A 112) located 25 kilometres northeast of the Brewery Creek mine. The claims are contiguous with the Java claims held by Homestake and gives them a large land package in the area. The 1998 program involved geological mapping, sampling, hand and blast trenching. This exploration program was designed to identify and evaluate targets with potential for bulk tonnage gold, contact gold skarn and gold replacements in calcareous Upper Proterozoic-Lower Cambrian Hyland Group sediments adjacent to the mid-Cretaceous Mike Lake intrusive.

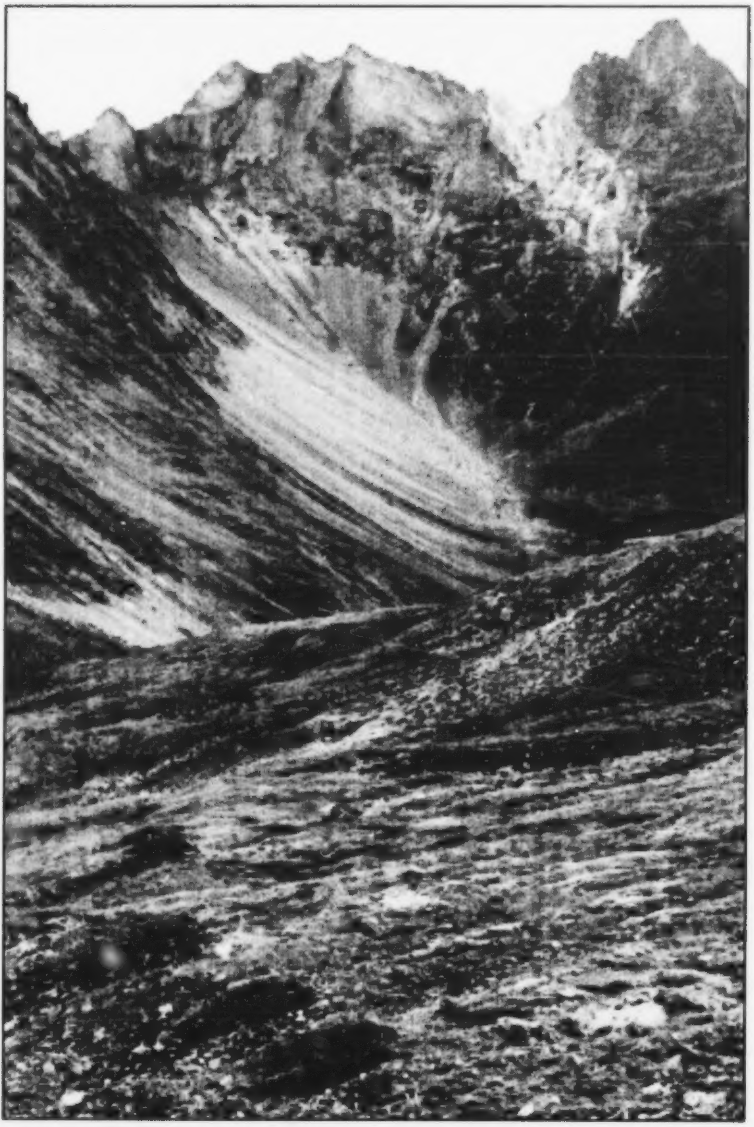


Figure 12. *Hand-dug pits (lower left) mark the lower skarn contact of a large pendant of limestone enclosed by granodiorite on the Horn claims.*

Canadian United Minerals evaluated several properties in the Tombstone Mountain area northeast of Dawson. Prospecting, silt and soil sampling and geophysics, followed by hand and helicopter portable Kubota trenching (Fig. 12), was performed on the **Horn** (NTS 116B/7) claims. The Horn claims are located approximately 8 kilometres east of the Marn (Yukon Minfile 116B 147) Cu-Au skarn deposit, which is estimated to contain 275,000 to 330,000 tonnes averaging 8.6 g/t Au, 1% Cu, 0.1% WO_3 and 17 g/t Ag. Mineralization at the Horn consists of high-grade Cu-Au skarn similar to the Marn. Mineralization at the Horn is located at the upper and lower contacts of a large pendant of Permian Takhandit Formation limestone enclosed by granodiorite of the Tombstone Plutonic Suite. Canadian United Minerals intends on continuing to evaluate the occurrence during the winter of 1998/99 with continued trenching and possibly bulk sampling.

In 1998, La Teko Resources Ltd. optioned the **Scheelite Dome** property (Yukon Minfile 115P 033) from Kennecott Canada Exploration. The road-accessible property, 25 kilometres northwest of Mayo, has been explored by Kennecott since 1994. During the 1998 field season, La Teko diamond-drilled 1268 metres in seven widely-spaced holes (Fig. 13). Drilling by La Teko was conducted on several targets within a 3.5 by 1.4 kilometre gold-in-soil (>40 ppb Au) and bedrock anomaly. These targets included chargeability and resistivity anomalies, as well as favourable geologic and structural domains within Upper Proterozoic to Lower Cambrian Hyland Group metasedimentary rocks adjacent to the mid-Cretaceous Scheelite Dome granite stock (Hulstein et al., this volume). Several styles of mineralization occur on the property with the primary target of the 1998 program being structurally controlled metasediment-hosted quartz-sulphide veins with bulk tonnage gold potential. Mineralization intersected in drilling consisted of silicification and sulphides including arsenopyrite, pyrite, pyrrhotite and stibnite, as well as crosscutting quartz veins. Mineralization was encountered in all drill holes, with the best intersection from hole 98-12, returning 7.7 metres of 3.67 g/t Au. More detailed geophysics in combination with the 1998 drill results will allow La Teko to focus on specific areas within the large gold anomaly, as well as to continue evaluating areas outside of the drill-tested area in 1999.

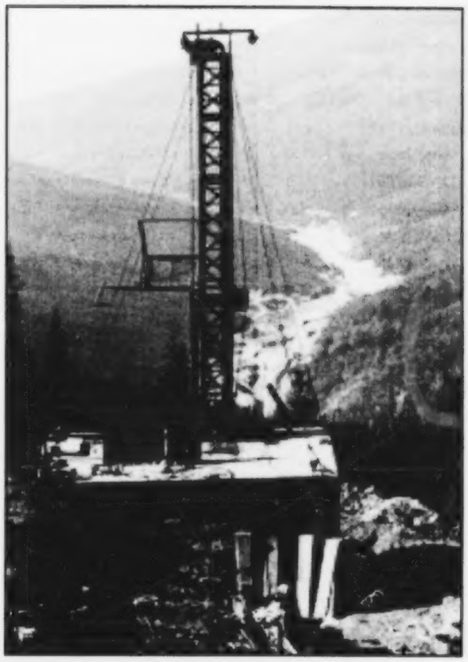


Figure 13. Extensive placer workings can be seen in Highet Creek which drains the Scheelite Dome property of La Teko Resources.

Moving further east in the Tombstone Intrusive Belt, Viceroy Resources, Ltd. optioned the **McQuesten** property (formerly the Wayne; Yukon Minfile 105M 029) from Eagle Plains and Miner River Resources. The property is located five kilometres west of Elsa in central Yukon, is accessible by a government-maintained road and is bisected by a power line. Viceroy conducted extensive excavator trenching (Fig. 14) totaling 3.3 kilometres, and a five-line kilometre Induced Polarization survey in the 1998 work program. Skarn and replacement styles of mineralization (semi-massive pyrrhotite) are hosted by calcareous metaclastic rocks and limestone of the Upper Proterozoic to Lower Cambrian Hyland Group. Variably mineralized (up to 2% pyrrhotite) and strongly sericitized quartz monzonite dykes of Cretaceous age cut stratigraphy on the western end of the property. Trenching in 1998 defined a 10-120 m wide zone of > 0.25 g/t Au over an east-west strike length of 2.5 kilometres. Arithmetic averages of vertical channel samples in trenching within the zone returned values up to 2.48 g/t Au over an 18 metre length in trench 98-11. Trench 98-14 returned a 40 metre length grading 1.24 g/t Au within

Figure 14. Time Termuende of Miner River Resources (right) and Rick Diment of Viceroy Resources examining trenches on the McQuesten property.

a wider zone of 80 metres grading 0.94 g/t Au. Previous wide-spaced reverse circulation drilling within the mineralized corridor returned values up to 3.2 g/t Au over 23 metres, 1.10 g/t Au over 33.5 metres and 2.1 g/t Au over 27 metres. Systematic drilling of the property is expected to begin in 1999 with the aim of defining a resource within the mineralized corridor.

YKR International Resources Ltd. conducted a small program consisting of a 15-line kilometre IP survey on the **Aurex** property (Yukon Minfile 105M 060) which is contiguous with the McQuesten property.

Teck Exploration explored the **Kiwi** property (NTS 105J/12) northeast of Ross River with a small program of trenching using a helicopter-portable Kubota backhoe. Epithermal gold mineralization is associated with quartz-feldspar porphyry dykes of probable Cretaceous age, intruding black graphitic shales of the Ordovician to Devonian Road River Group (Fig. 15). Silicification with minor pyrite and rare visible gold occurs in both the shales and intrusive rocks. Alteration consisting of silicification and sericitization also occurs over a widespread area.

Eagle Plains and Miner River Resources conducted several prospecting programs, as well as rock, silt and soil sampling on seven properties within the Tombstone Plutonic Suite. All the properties host gold mineralization either within or peripheral to plutonic rocks. The partners plan on drill-testing several targets in 1999, and are seeking joint venture partners on these properties.

Alliance Pacific Gold Corp. conducted a winter program of rotary drilling on the **Plata** mine property (Yukon Minfile 105N 003) in east-central Yukon. Sixteen vertical holes totaling 200 metres were drilled within the Thrust Zone, formerly known as the "P4 Zone." The Thrust Zone occupies a major gently southwest-dipping thrust fault that is associated with a 1 to 3 m wide quartz feldspar porphyry dyke of probable mid-Cretaceous age. Mineralization

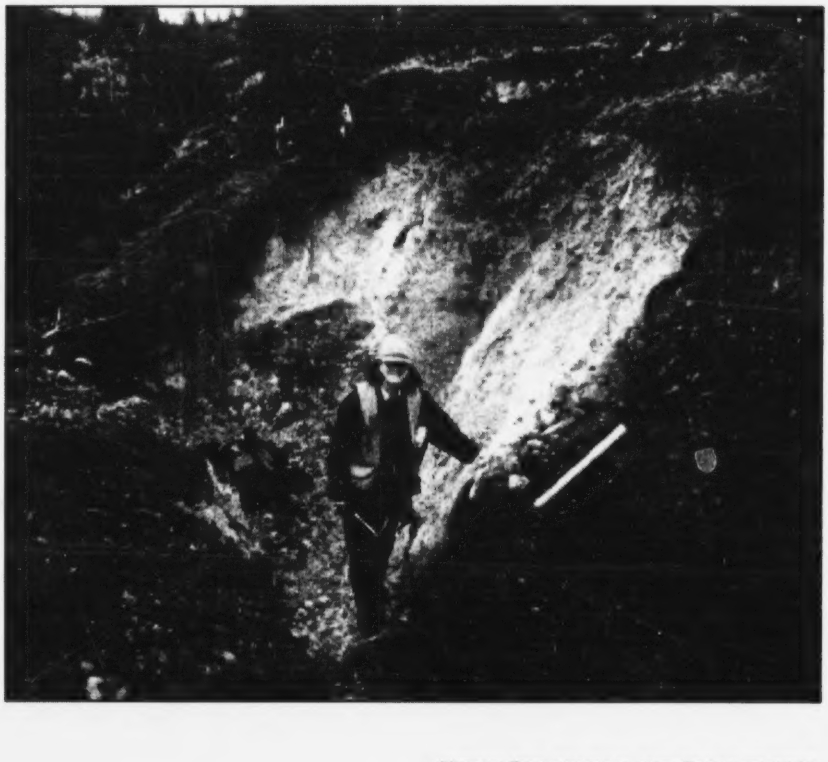


Figure 15. *Jean Pautler of Teck Exploration in a trench at the Kiwi property. Light-coloured quartz feldspar porphyry can be seen intruding black shales.*

consists of disseminated pyrite, arsenopyrite, tetrahedrite and other sulphosalts in a massive white quartz gangue. Lenses of massive pyrite-pyrrhotite-galena-sulphosalts are also present. Previous drilling has indicated a resource of 206,000 tonnes with an average grade of 267.5 g/t Ag and 3.3 g/t Au. Eleven holes intersected the zone in this year's drill program and returned an average grade of 653.4 g/t Ag and 3.3 g/t Au. The average width of the zone is 1.8 metres and it remains open in all directions.

The **Hy** gold prospect (NTS 105H/15) is 185 kilometres north of Watson Lake between the Hyland and Little Hyland rivers. The claims were originally staked by Phelps Dodge in 1996 after reconnaissance sampling yielded anomalous gold concentrations in silt and float samples in nearby creeks and outcrops. The claims are underlain by Upper Proterozoic to Lower Cambrian Hyland Group sedimentary rocks consisting of phyllite, quartzite and shale with lesser pebble conglomerate, limestone and grit. Mineralization consists of disseminations and clots of arsenopyrite, pyrite and galena in quartz veins and breccias exposed in isolated outcrops. Follow-up exploration this year consisted of prospecting, geological mapping, and extensions of the 1997 grid to the east and southeast, and collection of 266 soil samples and 27 rock samples. Geological mapping delineated two fault structures coincident with, and possibly related to, the East and West gold zones. Several of the rock samples returned highly anomalous gold concentrations accompanied by significant amounts of silver and arsenic. Samples from the West Zone returned up to 144.2 g/t gold from arsenopyrite-bearing quartzite and quartz vein material. Rock samples from the East Zone returned up to 9.9 g/t gold from arsenopyrite-bearing quartz vein material, quartz breccia and phyllite.

Barramundi Gold Ltd. conducted a program of soil sampling, induced polarization and electromagnetics and a small program of diamond drilling on the **Longline** project (Yukon Minfile 115N 024). The Longline project is located approximately 80 kilometres north of Beaver Creek straddling the Yukon-Alaska border. Barramundi has been exploring the property for the bulk tonnage gold potential of mineralization in the Moosehorn granodiorite, however in 1998, the company completed detailed work on a high-grade vein system (Fig. 16) exposed within the granodiorite. Mining of the vein in 1996 by a previous operator produced 1800 tonnes of material with a recovered grade of 19.0 g/t Au. Barramundi has applied for a Type B water licence in order to bulk-sample the vein system in 1999, while continuing with its evaluation of the bulk tonnage potential of the property.

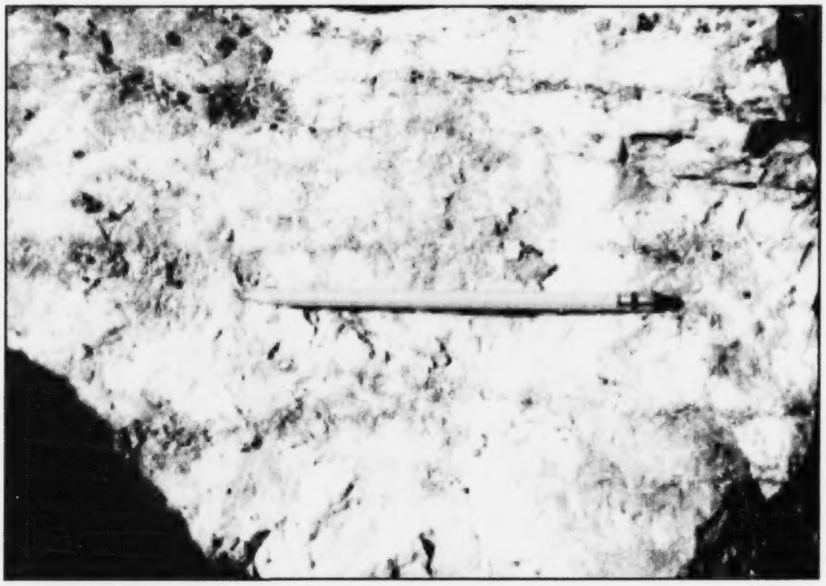


Figure 16. *High-grade quartz-sulphide mineralization from the Longline property.*

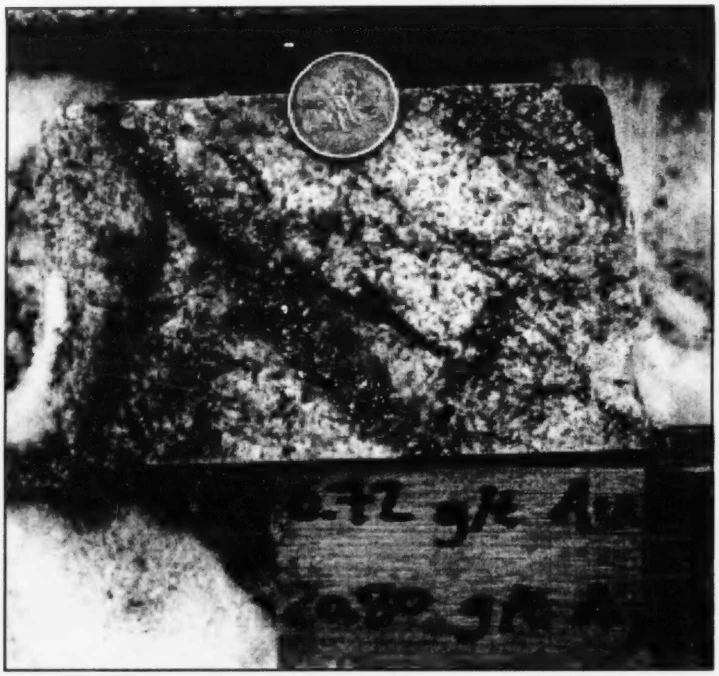


Figure 17. *Stringers of pyrite in a clay-altered plutonic breccia from the Porphyry Breccia zone at Mount Nansen.*

Columbia Gold Mines Ltd. conducted preliminary exploration work on the **JRV** property (Yukon Minfile 105K 051, 052, 053) located approximately 20 kilometres north of the town of Faro. The property covers the southeastern margin of the Cretaceous Anvil Batholith which intrudes Paleozoic metasediments. Three zones containing potential for open-pit bulk tonnage precious metal mineralization are targeted. Mineralization consists of broad zones of silicification and chalcedonic veining associated with argillic and phyllic alteration. Sulphide minerals include pyragyrite and tetrahedrite, galena, arsenopyrite and sphalerite. The Arseno Zone contains an area measuring 600 by 700 metres in which twelve samples of mineralization averaged 1.65 g/t Au and 138.2 g/t Ag. Follow-up work, including drilling, is planned for 1999.

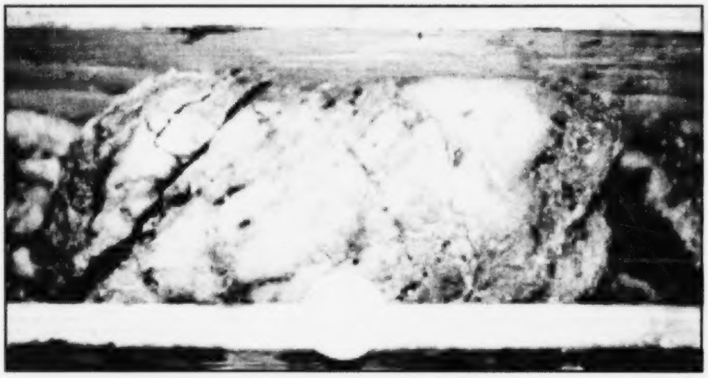


Figure 18. *Quartz-sulphide mineralization typical of veins from the Flex zone at the Mount Nansen mine.*

BYG Natural Resources conducted a large exploration program on their properties in the **Mount Nansen** (Yukon Minfile 115I 064, 065) area. Sixty diamond drill holes totaling 4844 metres were drilled on the Flex, Porphyry breccia, Tawa, Orloff-King and Brown McDade zones. Mining of the Brown-McDade Main vein, an oxidized quartz-sulphide epithermal vein, encountered a previously undiscovered carbonate-hosted gold-silver bearing, silicified sulphide rich breccia pipe separate from the Main vein (Stroshein, this volume). The irregular pipe-like body has a high-grade core with dimensions of approximately 15 by 20 metres enveloped by decreasingly mineralized and silicified brecciated carbonate rocks. Assays from the core within the open pit typically assay greater than 30 grams per tonne gold. Brecciated metamorphosed clastic rocks in the pipe have been intersected by drilling 60 metres down-plunge returning 23.8 metres of 11.7 g/t Au and 24 g/t Ag. A winter drilling program will continue testing the pipe as it presents an easily accessible, bulk tonnage underground mining target. Drilling of a high gold-in-soil geochemical anomaly, approximately 800 metres north of the Brown McDade open pit encountered a clay-altered plutonic breccia, with mineralization consisting of disseminated and stringer pyrite +/- galena-sphalerite (Fig. 17). Hole 98-198 ended within this zone and averaged 1.4 g/t Au and 11.1 g/t Ag over 23.8 metres. Other holes in the area encountered lower grade mineralization. The bulk of the 1998 drilling was conducted in the Flex Zone, which consists of a swarm of epithermal quartz-sulphide veins (Fig. 18) within a 425 by 55 metre area with a north-northwesterly trend. Infill drilling was conducted to upgrade confidence in the preliminary open pit design for the Flex Zone (81,700 tonnes grading 7.37 g/t Au and 312.5 g/t Ag). The drilling program successfully extended the vein system 75 metres to the north and 100 metres south along strike beyond the pit design. A 1997 stripping program within the Flex Zone helped define the geometry and structure within the zone. New veins discovered during the stripping program were intersected by the 1998 drilling, returning intersections up to 7.68 g/t Au and 107.6 g/t Au over 6.1 metres in hole 98-231. Further work, including bulk sampling and final feasibility studies, is planned for the Flex Zone in 1999.

An exploration program, consisting of geological mapping, rock sampling and ground geophysical surveys, was completed in the eastern part of the **Prospector Mountain** property (Yukon Minfile 115I 034, 036) of Troymin and Almaden Resources. The road-accessible property is located 50 kilometres northwest of the Mount Nansen mine. Previous work identified epithermal gold-silver mineralization on the property, while current work is directed toward the alkalic Cu-Au porphyry potential.

Partners Omni Resources and Arkona Resources and Trumpeter Yukon Gold conducted a program of geochemistry, geophysics and diamond drilling (Fig. 19) on the **Skukum Creek** (Yukon Minfile 105D 022) and **Goddell/Carbon Hill** projects (Yukon Minfile 105D 025) in 1998. The properties are located in the Wheaton river area 85 kilometres south of Whitehorse. Mesothermal quartz-sulphide deposits host drill-indicated resources of 825,000 tonnes grading 7.15 g/t Au in the Goddell deposit and 800,000 tonnes grading 7.6 g/t Au and 275 g/t Ag at the Skukum Creek deposit. Diamond drilling of five holes totaling 1322 metres was conducted to test previously identified high-grade gold vein targets in the Skukum Creek area. Unfortunately, mineralization of the same tenor as that identified on surface was not encountered in drilling. Two new areas of mineralization with many of the characteristics of the Goddell-style deposit were discovered in the Goddell/Carbon Hill area and exposed by hand trenching. Further work on these and several other untested targets is planned for 1999.

President Mines Ltd. conducted a program of geological mapping, prospecting and geochemistry on the **Gold Reef** property (Yukon Minfile 105D 037) in the Wheaton River area south of Whitehorse. Previous work identified high-grade epithermal mineralization on the property. The vein on the Gold Reef claim is 1.2 to 1.5 m wide and locally swells to 4.6 m of solid quartz, concordant with foliation in greenstone and schist of the Triassic Lewes River Group. Small lenses of arsenopyrite, galena, argentite, chalcopyrite and pyrite were found and one small pocket contained coarse, free gold, sylvanite and hessite. Work in 1998 has identified four main geochemical and geological targets within a 6 kilometre zone. Several gold bearing quartz-carbonate vein float trains were also identified within the zone.

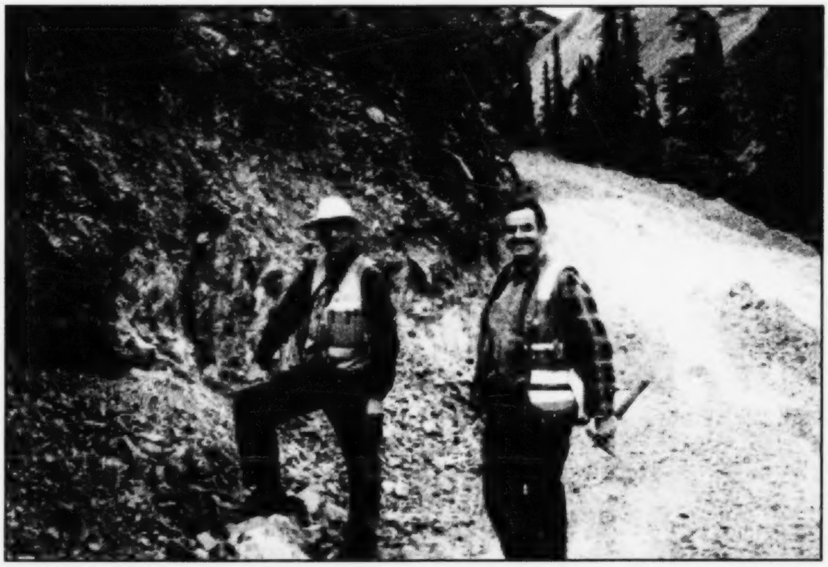


Figure 19. *Gary Wesa (left) and Terry Elliot at the Polaris zone on the Skukum Creek property in the Wheaton River area.*

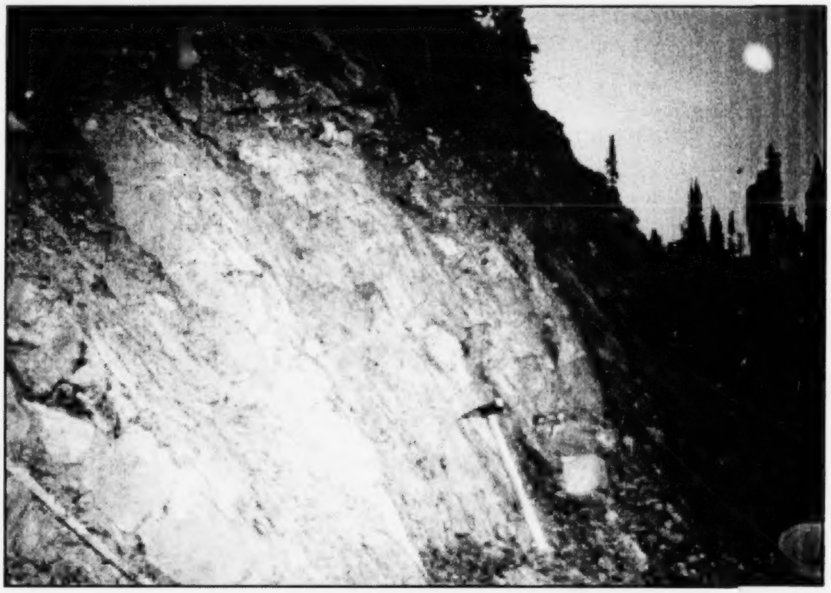
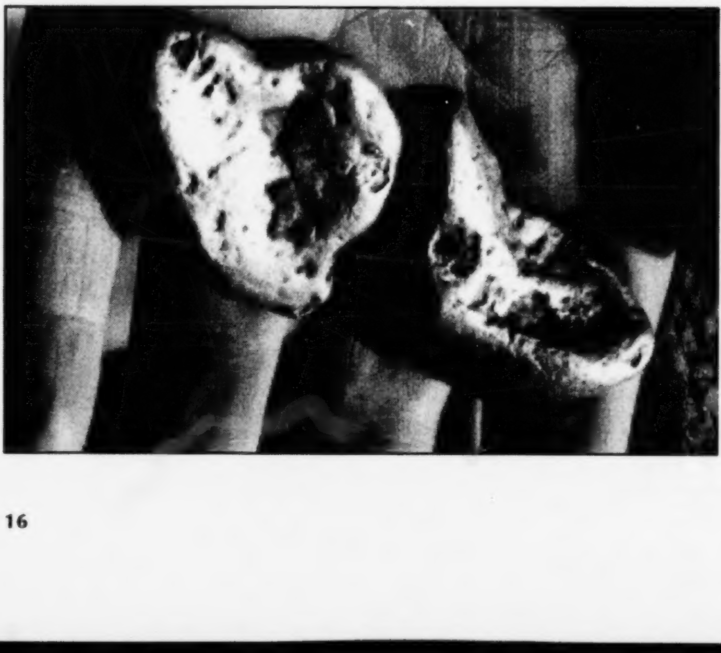


***Figure 20.** Limonitic-altered quartz sericite schist outcrop on Lake Creek at the Livingstone Creek property northeast of Whitehorse.*

Placer miner Max Fuerstner and Whitehorse geologist Larry Carlyle staked a large block of quartz claims over the productive creeks in the **Livingstone** (Yukon Minfile 105E 001, 042, 049, 054) camp, 90 kilometres northeast of Whitehorse. The area has never been systematically explored for hard rock mineralization despite a 100-year history of placer mining. Mineralization previously identified in the area consists of a 1-2 metre-wide quartz-sulphide vein with minor visible gold which returns assays up to 30 grams gold per tonne. Work in 1998 identified another style of mineralization exposed in an outcrop of limonitic and argillically-altered, sheared quartz-sericite schist (Fig. 20) on Lake Creek. A composite grab sample of this outcrop assayed 3110 ppb Au. Gold from the Livingstone camp is typically large (Fig. 21; nuggets up to 36 ounces, 1100 grams) and several nuggets containing octehedral impressions of magnetite crystals were observed. Magnetite is commonly observed in Paleozoic metamorphic units underlying the property and suggest that another undiscovered source of gold exists on the property.

Yukon Yellow Metal conducted a small program of A-size core drilling (Fig. 22) on the Shootamook Creek property (Yukon Minfile 105B 045). Three holes, totalling 101 metres, were collared from one setup on the Winnie showing. A granitic intrusive plug intense argillic alteration was encountered in all holes, with variable silicification and minor sulphide mineralization. Hole Mel-X2 encountered a zone at 28 metres depth with very fine-grained acicular arsenopyrite which assayed 1.9 g/t Au over 0.7 metres.

***Figure 21.** Two 5-ounce gold nuggets from Livingstone Creek.*



Brett Resources Inc. conducted a short program of geological mapping on the **Maui** property (NTS 105G/11), 80 kilometres southeast of Ross River. The program followed up on soil geochemical anomalies and gold bearing quartz-sulphide mineralization discovered during a grassroots program in 1997 by

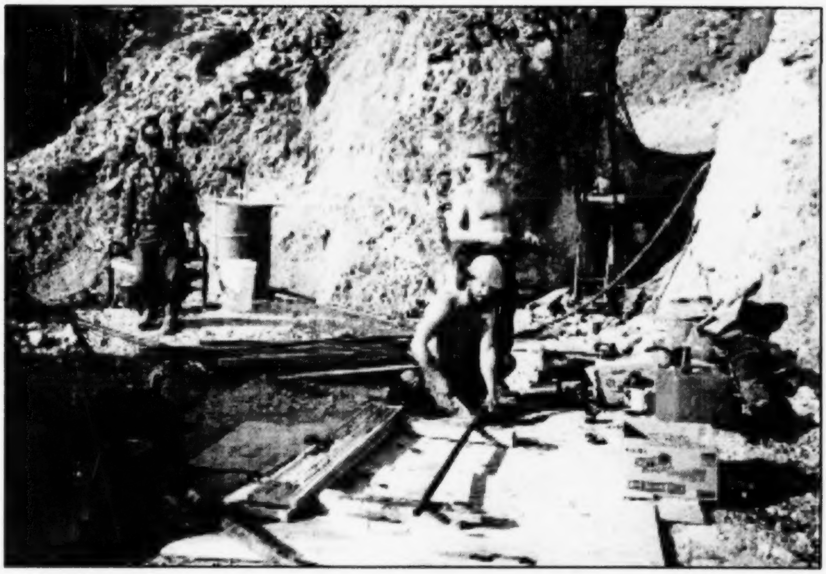


Figure 22. *AX drilling rig at the Shootamook Creek property of Yukon Yellow Metal.*

Whitehorse geologist Jim Dodge. The program was funded by the Yukon Mining Incentive Program. The property lies within Yukon-Tanana Terrane and contains a metasedimentary package of quartz-sericite to quartz-biotite garnet schists overlying a thin metavolcanic muscovite-quartz-feldspar schist which unconformably overlie megacrystic quartz monzonite (Tulk and Tucker, 1998). This package can be tenatively correlated with Unit 1, Unit 3 and the Mississippian Houle augen orthogneiss described in the adjoining mapsheet by Murphy (1997). A high-level quartz monzonite plug intrudes the orthogneiss (Dodge, 1997). Mineralization on the property includes a swarm of intrusive-related arsenopyrite-pyrite-quartz veins hosted in metasedimentary rocks. The widest of four veins was exposed over 0.4 metres by hand-trenching, and select samples assayed up to 5.8 g/t Au, 2500 ppm Bi, 17% As. A small massive sulphide body, conformable to foliation in the metavolcanic schist, returned values up to 3.0 g/t Au, 128 ppm Bi, 10% As and 6.3% Zn. The sulphides could not be traced along foliation for any significant distance. Brett returned the claims to Dodgex Ltd. of Whitehorse after completing the 1998 program.

Radius Exploration conducted a small diamond drilling program on the **Brik** (Yukon Minfile 116B 004) property (Fig. 23) near Dawson. Exploration targeted low-sulphide, structurally controlled, precious metal mineralization adjacent to an Eocene felsic volcanic centre and the Tintina Fault. Seven holes were completed to test IP and geochemical anomalies

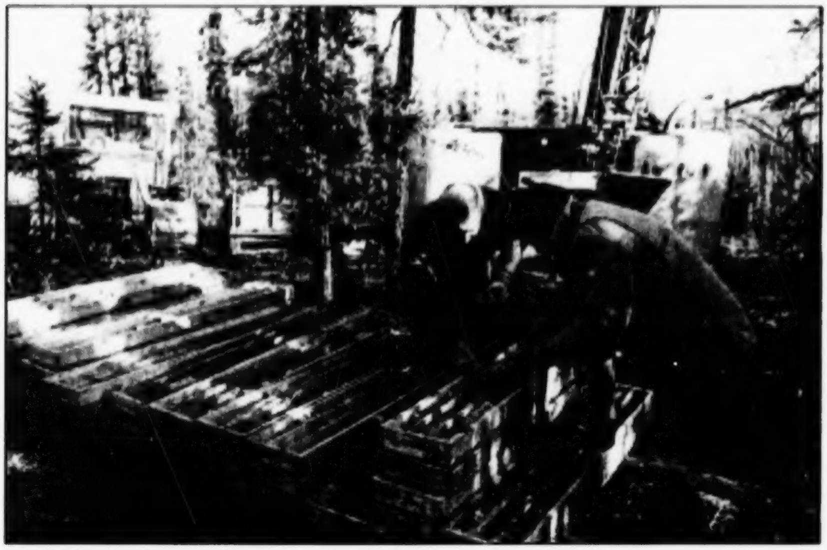


Figure 23. *Harmen Keyser (left) of Radius Exploration and Al Doherty of Aurum Consultants examine core from the Brik property.*

coinciding with a poorly exposed zone of epithermal-style alteration and mineralization in ultramafic rocks. Results of the drilling show that the zone of interest is a thin veneer of ultramafic rocks bounded by a sub-horizontal thrust fault within 25 metres of surface, underlain by graphitic schist. Anomalous gold grades were encountered in drilling, but no grades of economic significance were intersected.

BASE METAL EXPLORATION

Figure 24. *Helicopter-supported drilling was performed on the Wolf property.*

Since 1994, base metal exploration has been dominated by the search for volcanogenic massive sulphide deposits in the Finlayson Lake district. In 1998, exploration for base metals covered most areas of the Yukon; companies were seeking a wide range of commodities and deposit types. Although there were several active exploration projects in the Finlayson district, the level of exploration has declined dramatically from previous years. Exploration in the district is expected to increase with the acquisition by Expatriate Resources of Boliden Westmin's 60% share of the Wolverine deposit (6.2 million tonnes grading 12.7% zinc, 1.3% copper, 1.5% lead, 371 g/t silver and 1.76 g/t gold). Expatriate has stated its intention to move the project forward through resumed exploration and increased efforts in finding a metallurgical solution to the high selenium content of the Wolverine property; the property was idle in 1998. Exploration for VMS deposits continued in other areas of Yukon-Tanana Terrane apart from the Finlayson Lake district.

Atna Resources continued to expand the **Wolf** Pb-Zn-Ag volcanogenic massive sulfide deposit (Yukon Minfile 105G 008) optioned from YGC Resources in 1998, drilling 6625 metres in 30 holes, the Yukon's largest diamond drilling program (Fig. 24). Atna announced a drill-indicated resource for the deposit of 4.1 million tonnes grading 6.2% Zn, 1.8% Pb and 84 g/t Ag for the main Wolf deposit after the 1998 drilling. The Wolf is located 45 kilometres west of Cominco's Kudz Ze Kayah deposit in a belt of Mississippian volcanic rocks southwest of the Tintina Fault in Pelly-Cassiar terrane (Gibson et al.; and Hunt, this volume). Drilling was successful in expanding the deposit which now has a strike length of 600 metres and has been traced for a down dip length of 450 metres (Fig. 25). Two additional zones of massive sulphide mineralization have been found in the footwall of the main Wolf stratigraphic horizon. A new zone, the East Slope, was discovered 1200 metres along strike to the east of the Wolf deposit. Drilling in the East Slope Zone intersected three massive sulphide horizons within a 140 metre-thick sequence of mineralized felsic pyroclastic rocks. Drill hole WF98-33 intersected 4.0 metres of 4.63% Zn, 2.12% Pb and 30.0 g/t Ag in the uppermost sulphide horizon which is correlated with the main Wolf horizon. One other hole was drilled in the East Slope Zone approximately 60 metres downdip from hole WF98-33 and intersected two narrow mineralized horizons. The main Wolf horizon which

Figure 25. *High-grade massive sulphide core from the Wolf property.*

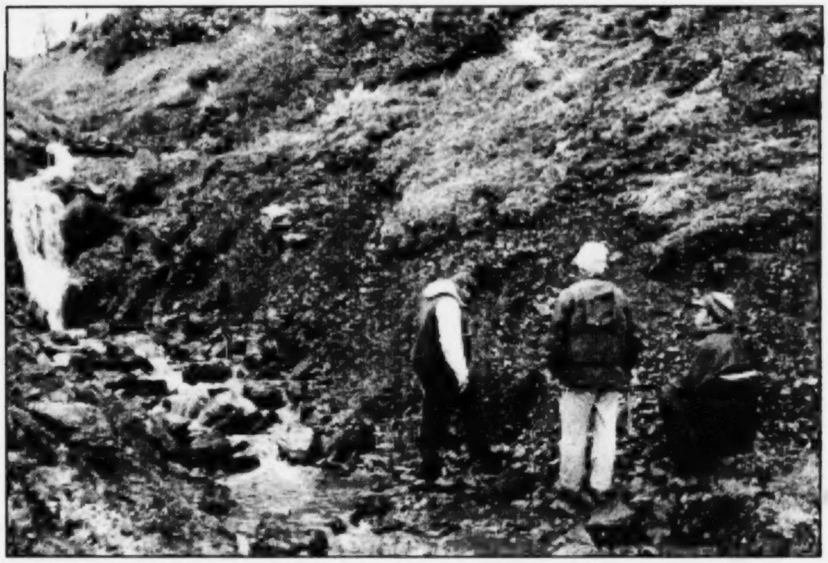


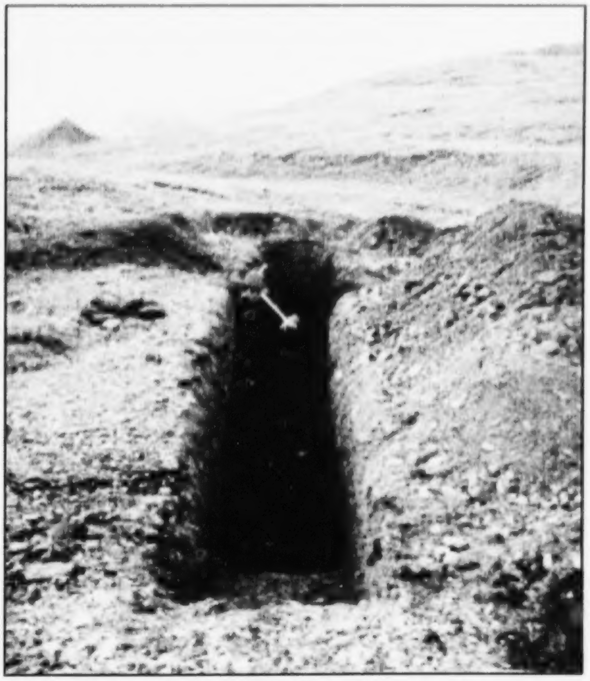
***Figure 26.** Willow Creek zone at the Starr property of Pathfinder and Petra Resources.*

remains open, and the additional zones discovered by the 1998 program will be further tested in 1999. Atna also drilled on the Fox property, optioned from Cominco, which adjoins the Wolf property. They also conducted prospecting, mapping and sampling programs on the Fire and Ice claims optioned from Eagle Plains/Miner River Resources. The Mamu property was also optioned from Oro Bravo Resources and received limited work. Atna also worked on their 100% owned Tree property hosted in the same belt of rocks.

Pathfinder Resouces and partner Petra Resources conducted their first full season of exploration on their extensive block of claims that extends to the northwest from the Wolf claims. The **Starr** property (Yukon Minfile 105G 090, etc.) covers 25 kilometres of the same volcanic stratigraphy that hosts the Wolf deposit. A program of silt and soil sampling, prospecting and geological mapping was conducted in late 1997 on numerous zones identified by prominent gossans, an airborne geophysical survey and a preliminary geological program. The program conducted by Equity Engineering successfully located massive sulphide mineralization consisting mainly of massive pyrite with trace galena and sphalerite (Fig. 26). This zone and several other promising areas will be explored in 1999.

In the Finlayson VMS district, exploration has declined, however several companies remained active in the emerging camp. Expatriate Resources has large land holdings in the Finlayson district and they continued to advance the potential of several properties with programs of geological mapping, sampling and hand trenching (Fig. 27). Several targets consisting of massive sulphide mineralization have been identified and remain to be tested by diamond drilling. In 1998, Expatriate announced a resource calculation for the **Ice** (NTS 105G/13, 14) deposit in the Finlayson district. The deposit contains 4,561,863 tonnes grading 1.48% Cu with minor gold, silver and cobalt. Approximately 3.4 million tonnes of the resource can be exploited by open-pit mining. Arcturus Resources also

***Figure 27.** A tidy hand trench excavated by Expatriate Resources personnel in the Finlayson Lake area.*



continued working on their **First Base** property (Yukon Minfile 105G 031), 17 kilometres west of Cominco's **Kudz Ze Kayah** deposit, with a small program of ground geophysics. Elsewhere in the Finlayson district, Cominco Exploration conducted the only drill program in the area on their Kudz Ze Kayah (Yukon Minfile 105G 117) property. Kudz Ze Kayah was the original discovery in the Finlayson district and contains open-pit mineable reserves of 11 million tonnes grading 5.9% Zn, 0.9% Cu, 1.5% Pb, 130 g/t Ag, and 1.3 g/t Au. Exploration on the **Wolverine** deposit (Yukon Minfile 105G 072) of Expatriate/Atna Resources was idle in 1998. Exploration is expected to resume in 1999 with legal issues surrounding ownership of the property resolved and metallurgical solutions to the high selenium content of the deposit being investigated.

Several properties continued to be evaluated in the Wolf Lake, Teslin and Quiet Lake areas for their VMS potential. Birch Mountain Resources conducted a small program of prospecting, geological sampling and mapping on the **Swift River** property (Yukon Minfile 105B 027) located 130 kilometres west of Watson Lake. Numerous Pb-Zn-Ag-Cu-Au showings occur on the property which is underlain by interbedded clastic and volcanic rocks of the Yukon-Tanana Terrane. Previous work has classified the mineralization as skarn based on the calc-silicate host rocks and mineralogy of most of the known showings. Birch Mountain has re-interpreted the geology and is exploring the property as a series of syn-sedimentary exhalative deposits with a significant regional and contact metamorphic overprint. Work in 1998 discovered a new showing consisting of medium-grained quartz-pyrrhotite-actinolite-sphalerite-calcite-galena mineralization approximately one metre thick, hosted in an argillaceous quartz-muscovite schist. The showing is poorly exposed on a steep talus slope and grab samples returned values up to 9.3% Zn, 2090 ppm Pb, 1716 ppm Cu and 30.8 ppm Ag (De Paoli, 1998). Further work, including drilling, is planned for 1999.

Fairfield Minerals Ltd. conducted programs including IP surveys, soil geochemistry, prospecting and hand and blast trenching on the **Cabin Lake** (NTS 105B/4) and **Caribou Creek** (NTS 105C/8) properties in southern Yukon. The properties are underlain by Paleozoic metavolcanic and metasedimentary rocks of the Yukon-Tanana Terrane. The main target on the properties is polymetallic massive sulphides. Work to date has outlined several copper and copper-zinc soil anomalies. Trenching in the areas of soil anomalies has uncovered disseminated pyrite-chalcopyrite mineralization in sheared quartz mica schists on the Cabin Lake property. Porphyry-style mineralization, consisting of quartz stringers with chalcopyrite and molybdenite within a granitic intrusive, has also been discovered there. Values up to 606 ppb Au and 56.6 ppm Ag with anomalous bismuth, lead, molybdenum and tungsten were obtained from larger angular quartz float in the area of the porphyry mineralization. At Caribou Creek, disseminated and stringer-type sulphide mineralization in quartz sericite schist and quartz-carbonate altered intermediate to mafic volcanic rocks were discovered.

Figure 28. Helicopter-supported drill at the Dromedary property of Blackstone and Geologix Explorations.

Tanana Exploration conducted a program of geological mapping, geochemical and lithogeochemical sampling, and prospecting, following up on multi-element soil geochemical anomalies coincident with airborne EM conductors delineated in 1997 on the **Bigtop** property (Yukon Minfile 105C 021). The property is underlain by interlayered carbonaceous shales, pyritic felsic volcanics and tuffaceous units of Yukon-Tanana Terrane. A number of discordant zones of silicified, sericitized and lesser chloritized rocks with quartz veining and disseminated sulphides were identified in the 1998 program. The best developed zone showed a strong depletion of Ca, Na and K, with the Na depletion being laterally extensive. Petrographic analysis of felsic volcanics has shown them to be primarily dacitic in composition with some porphyritic textures. Many samples were tuffaceous and contained carbonaceous matter, suggesting formation in a relatively shallow submarine environment. A compilation of all data collected during the past two seasons will assist in the delineation of a number of stratigraphic drill targets which are proposed to test the mineral potential of the property (S. Traynor, pers. comm., 1998).

Blackstone Resources and Geologix Explorations conducted a 3-hole, 535-metre drill program (Fig. 28) on the **Dromedary** Pb-Zn-Ag property in central Yukon. Sedimentary-exhalative style mineralization is hosted in Devono-Mississippian Earn Group sediments. Drilling was targeted at extending two mineralized horizons intersected by drilling in 1997. Pyrrhotite-siderite mineralization, with minor base metals, was encountered by the drilling. The best intersection was 2.0 metres of 3.66% Zn, 0.02% Pb and 2.3 g/t Ag in hole FRN98-05. The drilling indicated a thickening of the sulphide horizon to the west where gravity and magnetic anomalies remain open. Several other geophysical anomalies on the property remain to be tested.

After a long lapse, exploration for Pb-Zn-Ag deposits northeast of Mayo in the Kathleen Lakes area was resumed by Manson Creek and Prism Resources. The partners explored several silver-lead-zinc properties hosted in Proterozoic dolomite in the southern Wernecke Mountains. Work was directed at sampling and re-evaluating many of the known showings and deposits in the area, and included detailed silt sampling, detailed mapping, rock sampling, line-cutting and several small gradient IP surveys. Several styles of mineral occurrence exist on the properties including replacement, veins and possibly Mississippi Valley-type mineralization. The main areas explored were deposits and occurrences in the **Val/Vera** (Yukon Minfile 106C 083, 085) area, and the Craig deposit optioned from Falconbridge. The Vera deposit contains a resource calculated at the end of 1981 of 850,000 tonnes averaging 306 g/t Ag and 3.7% combined Pb-Zn. Previous work on the Vera included extensive diamond drilling and 720 metres of underground development. The Val trend contains nine silver-lead occurrences (Fig. 29) located within Middle Proterozoic Gillespie Group dolomite that is unconformably overlain by carbonate rocks of the Late Proterozoic Pinguicula Group. The vein-like South Hill (South) Zone has an average width of 4.5 m and has been explored by drilling for about 300 m along strike and 250 m below surface. Drill-

Figure 29. *George Sivertz of Manson Creek Resources extols the virtues of the Val/Vera trend in the southern Wernecke Mountains.*

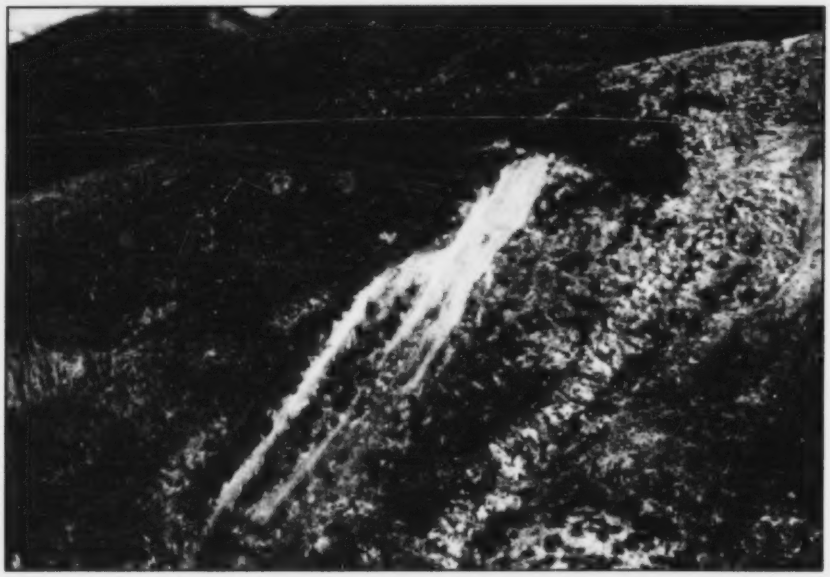


Figure 30. *Ariel view of the kill zone associated with the Craig deposit in the Kathleen Lakes area. Manson Creek Resources re-evaluated the deposit in 1998.*

indicated reserves are 272,000 tonnes grading 137 g/t Ag. The Big Red Zone also in this trend appears to be an irregular replacement style of deposit and has a drill-indicated potential of 60,000 tonnes grading 1030 g/t Ag. Manson Creek also optioned the **Craig** (Yukon Minfile 106C 073) deposit (Fig. 30) from Falconbridge and included it in the 1998 exploration program. Previous diamond drilling on the Craig Main Zone has outlined a mineral resource of 964,000 tonnes grading 112 g/t Ag, 13.5% Zn and 8.5% Pb. In 1998, work included exploration of several showings hosted within a 6.5 kilometre trend of the "Craig dolomite" on claims owned 100% by Manson Creek. Further work, including diamond drilling, is planned for 1999.

Nordac Resources Ltd. explored the **Blue Heaven** property (Yukon Minfile 105B 020) for both its high-grade small tonnage and lower grade bulk tonnage silver potential. Blue Heaven is located 38 kilometres by gravel road north of the Alaska Highway near Rancheria in south central Yukon. Exploration in the area has increased with recent activity at the Silvertip deposit (2.57 million tonnes of 325 g/t Ag, 6.4% Pb, 8.8% Zn) of Imperial Metals Corporation located approximately 60 kilometres to the southeast in British Columbia. The H Zone (Fig. 31) at Blue Heaven consists of high-grade silver veins hosted in a quartz sericite schist. The H-1 vein contains massive galena with varying amounts of banded sphalerite, arsenopyrite and tetrahedrite. Trenching on the H-1 returned a high-grade assay of 12,376 g/t Ag over 94 centimetres. The Blue Zone consists of galena

Figure 31. *Tom Becker of Nordac Resources at the H zone on the Blue Heaven property in southern Yukon.*

and sphalerite in siderite replacement bodies at the base of a limestone-skarn unit. Chip sampling from a trench in the Blue Zone returned a weighted average of 61.1 g/t Ag, 4.0% Pb and 3.8% Zn over 29.6 metres. Trenching, bulk sampling and diamond drilling is planned for 1999.

Nordac also explored the **Quarterback** property located 18 kilometres east of Blue Heaven. The QB#1 Zone was drilled in 1997 with the best result from drilling returning 1.75 metres of 107.5 g/t Ag, 8.4% Pb and 13.5% Zn. Exploration in 1998 resulted in the discovery of the QB#2 Zone located 3 kilometres to the west of the 1997 drilling. Hand trenching downslope from the discovery outcrop, a jasperoid-altered limestone, exposed mineralization which assayed 151.1 g/t Ag, 2.52% Pb, 0.91% Zn and 0.34% Cu over 15 metres. An extensive silver-lead-zinc-copper soil anomaly was also defined in the discovery outcrop area.

__Figure 32.__ Blackstone and Glenhaven Resources conducted helicopter-supported drilling on the Taiga Ni-Zn-PGE property.

__Figure 33.__ Limestone balls mark the immediate footwall to the Ni-Zn-PGE horizon in the MM grid extension area on the Taiga property.

Nordac also acquired, by staking, the Northern Dancer property, which contains the **Logtung** deposit (Yukon Minfile 105B 039), straddling the B.C.-Yukon border. The tungsten-molybdenum porphyry deposit contains a geological resource of 229 million tonnes grading 0.14% WO_3 and 0.05% MoS_2. Nordac conducted exploration immediately south of the deposit, where a quartz vein swarm contains beryl, wolframite and scheelite.

Blackstone and Glenhaven Resources conducted a helicopter-supported diamond drill program (Fig. 32) totaling 832 metres in 14 holes on the **Taiga** Ni-Zn-PGE property 100 kilometres northeast of Dawson. Stratabound pyrite-vaesite containing nickel-zinc mineralization with elevated Mo, Au and PGEs, is hosted in baritic and carbonaceous shales of the middle member of the lower Middle Devonian Earn Group. Drilling was conducted in the MM grid area where a 1997 drill program encountered significant mineralization (5.3 metres of 1.42% Ni and 0.70% Zn) in the stratabound horizon. Drilling was also conducted in the MM grid extension area where mapping, prospecting and soil sampling identified the favourable horizon (Fig. 33). Drilling was successful in extending the horizon, however no intersections of the same tenor as that in 1997 were encountered. Drilling in the MM grid in 1998 encountered anomalous values for Ni-Zn when intersecting the favourable horizon. The

best result was 1265 ppm Ni and 8320 ppm Zn over 0.9 metres in hole REN98-13. Hole REN98-25 in the MM grid extension intersected 2490 ppm Ni, 1640 ppm Zn over 1.41 metres. Three unexpected gold intersections associated with late-stage calcite and gypsum veinlets were also reported including 9.64 g/t Au over 1.61 metres and 1436 ppb Au over 0.75 metres in hole REN98-15.

Blackstone and Glenhaven also explored several properties to the east and north of the Taiga, targeting additional areas anomalous in Ni-Zn, identified from a large silt and soil sampling program conducted by UMEX in 1976-77. Ni-Zn soil anomalies were further defined with grid-based soil sampling; prospecting located additional Ni-Zn mineralization within the favourable horizon. The partners are evaluating how to further assess this enigmatic but highly prospective belt of rocks.

Blackstone conducted a program of grid establishment, geologic/structural mapping and soil and rock chip sampling on the **Monster** property (Yukon Minfile 116B 084), northeast of Dawson. The Monster property is located within the Coal Creek Inlier, an oval-shaped and east-trending window of Middle and Late Proterozoic clastic rocks that have been penetrated by mineralized breccias and cut by mafic sills and dykes. This belt of rocks shows distinct similarities in age, tectonic setting, alteration, and mineralization to Proterozoic iron-oxide deposits such as Olympic Dam (2 billion tonnes grading 1.6% copper, 0.6 g/t gold, 0.06% uranium oxide and 3.5 g/t silver) in Australia. Blackstone is actively seeking a joint venture partner for this property.

Eagle Plains Resources and CanAustra Resources carried out a small seismic and gravity geophysical survey followed by prospecting and geochemical sampling on the **Rusty Springs** property (Yukon Minfile 116K 003) in northern Yukon. The seismic work indicated that the siliceous limonitic stratabound horizon which hosts Cu-Pb-Zn-Ag mineralization on the property, extends to the east under a wide tussock-covered valley. The gravity survey identified two gravity highs underlying the valley. These targets are planned to be tested with further geophysics and drilling in 1999.

Liberty Minerals Exploration Inc. conducted a program of hand- and blast-trenching, followed by 339 metres of helicopter-supported diamond drilling in four holes on the **AZ** (Yukon Minfile 115F 051) property. The property is located approximately 40 kilometres south of Beaver Creek in western Yukon. Copper-gold mineralization on the property is hosted in pyroxene-magnetite and garnet-quartz-epidote skarn developed within basalts of the Middle Triassic Nikolai Group in Wrangellia terrane (Fig. 34). Surface sampling by Noranda in 1992 in the discovery outcrop area of garnet-magnetite-epidote skarn with disseminated to semi-massive chalcopyrite, returned values up to 8 g/t Au, 171.4 g/t Ag and 10.1% Cu. Trenching in 1998 away from the discovery outcrop failed to expose mineralization of the same tenor, and suggested that the pyroxene-magnetite skarn was the more favourable host to copper-gold mineralization. Drilling targeted magnetic anomalies, defined by a detailed magnetic survey conducted in 1997, and intersected a large (89 metre thick) section of mixed garnet-silicate and magnetite-pyroxene skarn in DDH 98-5. Sulphide minerals were rare in the garnet-silicate skarn while the pyroxene-magnetite skarn was mineralized with disseminated pyrite and chalcopyrite (< 1%). The best result was 2184 ppm Cu, 0.24 g/t Au and 1.6 g/t Ag from pyroxene-magnetite skarn from DDH 98-5. DDH 98-6 also intersected skarn lithologies before intersecting a coarse-grained hornblende-quartz diorite and alaskite (Doherty and Clarke, 1998).

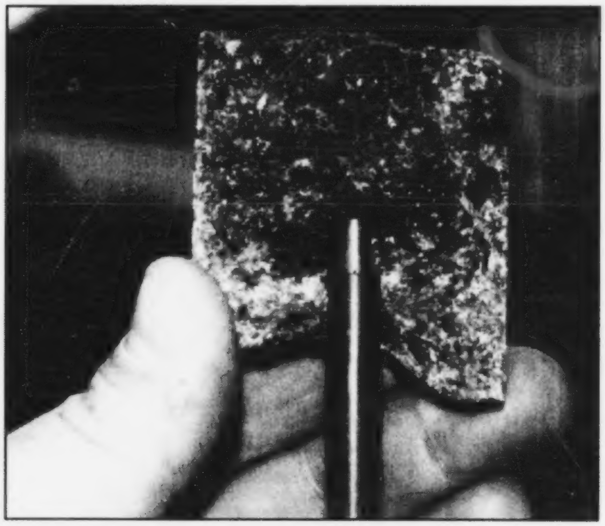


Figure 34. *Pyroxene-magnetite skarn with minor chalcopyrite from the AZ property.*

Rob Hamel and partner H. Coyne and Sons continued excavator trenching on the Hat claims (Yukon Minfile 105D 053), which are along strike with the mined-out War Eagle deposit (Fig. 35) in the Whitehorse Copper Belt. Calc-silicate skarn consisting of garnet, diopside and wollastonite, with chalcopyrite and bornite is exposed over a 200 metre strike length and up to 25 metres width. High-grade skarn in trenches approximately 400 metres north of the War Eagle yielded chip samples up to 9.58% Cu and 1.0 g/t Au over 1.5 metres.

GEMSTONES

Late in the 1998 season, Expatriate Resources reported a discovery of emeralds in the Yukon. The location and mode of occurrence remains confidential. The emeralds have been examined by J.H. Montgomery, Ph.D., P.Eng., who has stated that "some near gem-quality stones are present." The occurrence will be further evaluated for its gemstone potential in 1999.

COAL AND INDUSTRIAL MINERALS

Cash Resources Ltd. conducted a program of excavator trenching at the **Division Mountain Coal** (Yukon Minfile 115H 013) project. Trenching was conducted at Cub Mountain northeast of the Division Mountain coal resource. The property is located 90 kilometres northwest of Whitehorse near Braeburn and is 18 kilometres southwest of the main power transmission line to Carmacks and Faro. Cash Resources estimates drill-indicated raw coal reserves at 54.7 million tonnes. Usibelli Coal mine, Inc. (UCM) of Healy, Alaska entered into an agreement with Cash Resources to acquire 50%, or alternatively all of Cash's coal properties in the Yukon. UCM is a privately owned corporation which has been involved in the coal mining industry including mining, exportation and power plant operation in Alaska since 1943.

A private Yukon exploration company continued evaluating the **Braeburn Lime** (NTS 105E/ 5) project. Seven reverse circulation drill holes totaling approximately 200

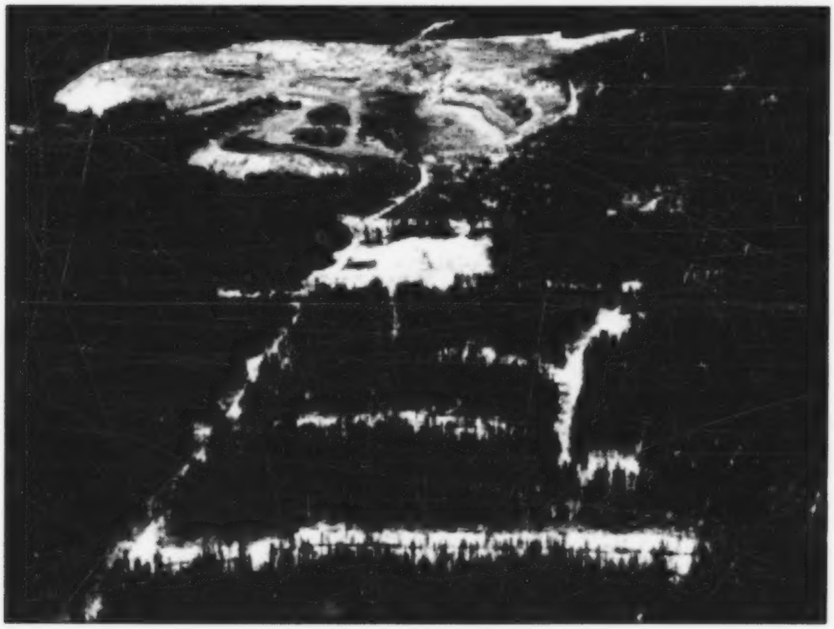


Figure 35. Trenching along strike from the mined-out War Eagle Pit in the Whitehorse Copper Belt has exposed calc-silicate skarn containing chalcopyrite and bornite.

metres were drilled testing near-surface high purity Triassic Lewes River Group limestone. The property is road-accessible midway between Whitehorse and Carmacks.

ACKNOWLEDGMENTS

This report is based on public information gathered from many sources. It includes information provided by companies through press releases, property summaries provided to the department and from property visits conducted in the 1998 field season. The cooperation of companies and individuals providing information and their hospitality during field visits are gratefully acknowledged. Editing by Diane Emond, Charlie Roots and Leyla Weston greatly improved this report.

Companies and individuals exploring in the Yukon and wishing to be included in future reports are encouraged to contact the author.

REFERENCES

DePaoli, G., 1998. Assessment report on the Swift River property, Yukon Territory. Mineral Resources Directorate, Yukon, Indian and Northern Affairs Canada.

Diment, R. and Craig, S., 1999 (this volume). Brewery Creek gold deposit, central Yukon. *In:* Yukon Exploration and Geology 1998, C.F. Roots and D.S. Emond (eds.), Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 225-230.

Dodge, J., 1997. 1997 Yukon Mining Incentive Program report on the Maui claims, Yukon Territory. Unpublished report, Mineral Resources Branch, Department of Economic Development, Yukon Government.

Doherty, R.A. and Clarke, J.A.J., 1998. Trenching and diamond drilling on the AZ claims (NTS 115F/15). Assessment Report #093885. Mineral Resources Directorate, Yukon, Indian and Northern Affairs Canada.

Gibson, A.M., Holbek, P.M. and Wilson, R.G., 1999. The Wolf property – 1998 update: Volcanogenic massive sulphides hosted by rift-related, alkaline, felsic volcanic rocks, Pelly Mountains, Yukon. *In:* Yukon Exploration and Geology 1998, C.F. Roots and D.S. Emond (eds.), Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 237-242.

Hulstein, R., Zuran, R., Carlson, G.G. and Fields, M., 1999 (this volume). The Scheelite Dome gold project, central Yukon. *In:* Yukon Exploration and Geology 1998, C.F. Roots and D.S. Emond (eds.), Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 243-248.

Hunt, J.A., 1999 (this volume). Preliminary stratigraphy and distribution of Devono-Mississippian massive sulphide-bearing volcanic rocks in the Mount Vermilion (Wolf) area, Pelly Mountains (105G/5 and G/6), southeast Yukon. *In:* Yukon Exploration and Geology 1998, C.F. Roots and D.S. Emond (eds.), Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 73-90.

Stroshein, R., 1999 (this volume). A summary report on the geology of the Brown-McDade gold-silver deposit, Mount Nansen mine area, Yukon. *In:* Yukon Exploration and Geology 1998, C.F. Roots and D.S. Emond (eds.), Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 231-236.

Tulk, L. and Tucker, T., 1998. Report on geological and geochemical surveys on the Maui property, Yukon Territory. Assessment Report #093890, Mineral Resources Directorate, Yukon, Indian and Northern Affairs Canada.

Yukon Minfile. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada. Also available from Hyperborean Productions, Whitehorse, Yukon.

APPENDIX 1: 1998 EXPLORATION PROJECTS

BS - Bulk Sample
D - Development
DD - Diamond Drilling
ES - Environmental Studies
F - Feasibility
G - Geology
GC - Geochemistry
GP - Geophysics
M - Mining
PD - Percussion Drilling
PF - Pre-feasibility
R - Reconnaissance
T - Trenching
U/GD - Underground Development

PROPERTY	COMPANY	MINING DISTRICT	MINFILE # (1:50 000 NTS)	WORK TYPE	COMMODITY
Alp, Nug, Old, Nut, Drag, May	Eagle Plains/ Miner River Resources	Mayo	105O 004, 048, 039, 044 105J 007, 115P 056	G,GC	Au
Am	Nordac Resources	Whitehorse	115F 048	G,GC	Cu-Au
Aurex	YKR International	Mayo	105M 060	G,GP	Au
AZ	Liberty Mineral	Whitehorse	115F 051	G,GC,DD	Cu-Au
Bigtop	15053 Yukon Inc.	Whitehorse	105C 021	G,GC,T	Pb-Zn-Cu-Ag-Au
Blue Heaven	Nordac Resources	Watson Lake	105B 020	G,GC,T	Ag-Pb-Zn-Cu
Braeburn Lime	Liberty Minerals	Whitehorse	(105E/5)	G,GC,RC	$CaCO_3$
Brewery Creek	Viceroy Resources	Dawson	116B 160	M,G,GC,RC	Au
Brik	Radius Exploration	Dawson	116B 004	G,DD	Au
Cabin Lake, Caribou Creek	Fairfield Minerals	Watson Lake	(105B/4 105C/8)	G,GC,T	Pb-Zn-Cu-Ag
Clear Creek	Newmont/New Millenium	Mayo	115P 012, 013	GP	Au
Cy/St	Eagle Plains/ Miner River Resources	Watson Lake	105F 102	G,GC	Pb-Zn-Ag
DDL	Nordac Resources	Whitehorse	105E 006	GC,T	Cu-Au
Division Mountain	Cash Resources	Whitehorse	115H 013	G,T	Coal
Dromedary	Blackstone Resources Geologix Explorations	Whitehorse	105L 031, 051	G,DD	Pb-Zn-Ag-Au
FER	Rimfire Minerals	Watson Lake	(105H/15)	G,GC	Au
Fire/Ice	Atna Resources/ Eagle Plains-Miner River	Whitehorse	105F 071, 073	G,GC,GP	Pb-Zn-Ag
First Base	Arcturus Resources	Watson Lake	105G 031	GP	Pb-Zn-Cu-Au-Ag
For Sure/Big Time/ Got It/Gotcha	Prospector International	Mayo	105O 024	G,GC	Au
Fox	Atna Resources/Cominco	Whitehorse	105G 008	G,GC,GP	Pb-Zn-Ag
Gates Creek	Viceroy/Tr'on dek Hwech'in First Nation	Dawson	(116A/4, 115P/13)	G,GC	Au
Goddell, Skukum	Omni/Arkona/Trumpeter	Whitehorse	105D 025, 022	G,DD	Au-Ag
Harlan	Viceroy Resource Corp.	Mayo	(105O/4/5)	G,GC	Au
Hat	Coyne & Sons	Whitehorse	105D 053	G,GC,T	Cu-Au-Ag
Horn	Canadian United Minerals	Dawson	(116B/7)	G,GC,GP	Au

PROPERTY	COMPANY	MINING DISTRICT	YUKON MINFILE (prefix is NTS map #)	WORK TYPE	COMMODITY
Hy	Paramount Ventures/ Phelps Dodge	Watson Lake	(105H/15)	G,GC	Au
Java/Lorrie	Homestake Canada	Dawson	116A 012, 021	G,GC,T	Au
JRV	Columbia Gold Mines	Watson Lake	105K 051, 052, 053	G,GC	Au-Ag
Kathleen Lakes	Manson Creek Resources	Mayo	106C 065, 083, 085, 073	G,GC,GP	Ag-Pb-Zn
Keno Hill	United Keno Hill	Mayo	105M 001	D	Ag-Pb-Zn
Kiwi	Teck Exploration	Whitehorse	(105J/12)	G,GC,T	Au
Kudz Ze Kayah	Cominco	Watson Lake	105G 117	G,DD	Pb-Zn-Cu-Ag-Au
Livingstone	Larry Carlyle/ Max Fuestner	Whitehorse	105E 1, 042, 049, 054	G,GC,T	Au-Ag
Longline	Barramundi Gold Ltd.	Whitehorse	115N 024	G,GC,DD	Au
McQuesten	Viceroy/Miner River/ Eagle Plains Resources	Mayo	105M 029	G,GC,T	Au
Mamu	Atna Resources/ Oro Bravo	Whitehorse	105F 013	G,GC,GP	Pb-Zn-Ag
Marlin	Northern Rhodonite	Whitehorse	105C 017	M	Rhodonite
Maui	Brett Resources	Watson Lake	(105G/11)	G,GC	Au
Mel	International Barytex	Watson Lake	95D 005	G	Pb-Zn-Ag
Minto	Minto Resources	Whitehorse	115I 021, 022	D	Cu-Ag-Au
Monster	Blackstone Resources	Dawson	116B 084, 102, 103	G,GC	Cu-U-Au-Ag
Mos	Barker/Risbey	Dawson	115N 039, 040	G,GC	Au-Ag
Mount Nansen	BYG Natural Resources	Whitehorse	115I 064, 065	M,G,GC,T,DD	Au-Ag
Northern Dancer	Nordac Resources	Watson Lake	105B 039	G,GC	WO_3, MoS_2
Oki-Doki	International Kodiak	Dawson	(116B/1, A/4)	G,GC,T,GP	Au
Pigskin, QB	Nordac Resources	Watson Lake	105B 107, 098	G,GC,T	Ag, Pb, Zn
Plata	Alliance Pacific Gold	Mayo	105N 003	PD	Au-Ag
Prospector Mountain	Troymin/Almaden Res.	Whitehorse	115I 034, 036	G,GC	Au-Ag
Revenue	YKR International	Whitehorse	115I 042	G,GP	Cu-Au-Ag-WO_3-MoS_2
Rusty Springs	Eagle Plains Resources CanAustra Resources	Dawson	116K 003	G,GP	Ag-Cu-Pb-Zn
Scheelite Dome	La Teko/Kennecott	Mayo	115P 033	G,GC,GP,DD	Au
Screamer	Prospector International	Mayo	115P 040	G	Au
Shootamook	Yukon Yellow Metal	Watson Lake	105B 045	DD	Au
Starr	Pathfinder/ Petra Resources	Watson Lake	105G 090, etc	G,GC	Pb-Zn-Ag
Sun/Sprogge	Viceroy/Battle Mountain	Watson Lake	105H 034	G,GC	Au
Swift River	Birch Mountain Resources	Watson Lake	105B 027	G	Pb-Zn–Cu-Ag
Taiga	Blackstone Resources Glenhaven Resources	Dawson	116B 128	G,GC,DD	Ni-Zn-Mo-Au-PGE

PROPERTY	COMPANY	MINING DISTRICT	YUKON MINFILE (prefix is NTS map #)	WORK TYPE	COMMODITY
Tea	Coyne & Sons	Watson Lake	105O 020	M	Barite
Tree	Atna Resources	Whitehorse	105F 095	G,GC,GP	Pb-Zn-Ag
Wash	Nordac Resources	Whitehorse	115G 100	G,GC,T	Ni-Cu-Au-PGE
Wellgreen	Northern Platinum	Whitehorse	115G 024	G,GC	Ni-Cu-PGE
Wolf	Atna Resources	Whitehorse	105G 008	DD,G,GC	Pb-Zn-Ag
Yukon Regional	Kennecott Canada	Various		R,G,GC	Au
Yukon Regional	Hudson Bay	Various		R,G,GC	Au
Yukon Regional	Homestake	Various		R,G,GC	Au
Yukon Regional	Viceroy Resources	Various		R,G,GC	Au
Yukon Regional	Phelps Dodge	Various		R,G,GC	Au
Yukon Regional	Teck Exploration	Various		R,G,GC	Au
Yukon Regional	Eagle Plains/Miner River	Various		R,G,GC	Au
Yukon Regional	Barrick	Various		R,G	Au
Yukon Regional	Placer Dome	Various		R,G	Au

APPENDIX 2: 1998 DRILLING STATISTICS

PROPERTY	COMPANY	DIAMOND DRILL		RC/PERCUSSION DRILL	
		METRES	# HOLES	METRES	# HOLES
AZ	Liberty Minerals	339	4		
Brik	Radius Exploration	375	7		
Brewery Creek - exploration	Viceroy Resources			6009	82
Brewery Creek - minesite infill	Viceroy Resources			7961	137
Dromedary	Blackstone/Geologix	534.6	3		
Fox	Atna/Cominco	945			
Kudz Ze Kayah	Cominco	1750	11		
Longline	Barramundi Gold	214	4		
Mount Nansen	BYG Resources	4844	60		
Plata	Alliance Pacific Gold			200	16
Scheelite Dome	La Teko/Kennecott	1250	7		
Shootamook	Yukon Yellow Metal	101	3		
Skookum Creek area	Omni/Arkona/Trumpeter	1350	5		
Strike	Cominco	200	2		
Taiga	Blackstone/Glenhaven	832.2	14		
Wolf	Atna/YGC Resources	6625	30		
TOTAL		**19,360**		**14,170**	

PLACER MINING OVERVIEW – 1998

William LeBarge
Yukon Geology Program

Low gold prices continued to daunt the Yukon's placer mining industry in 1998, resulting in a decrease in both production and employment. Many operations were forced to downsize by reducing personnel, operating one shift instead of two. Other operations had water licenses but did not mine, choosing instead to explore for better ground or maintain equipment. Several operations selectively mined only high-grade areas, preferring to leave the less economic ground for times when the gold price has improved.

A total of 161 mines operated, with approximately 600 people directly employed in the industry. This represents a 6% drop in the number of mines and a 20% drop in employment from 1997. Over 80% of the placer gold was produced from unglaciated regions of the Yukon including Klondike, Indian River, west Yukon (Fortymile, Sixtymile, Moosehorn) and lower Stewart River. The remaining gold came from glaciated regions including Clear Creek, Mayo, Dawson Range, Kluane and Livingstone.

Gold production in 1998 totalled 90,288 crude ounces (2,808,273 g), compared to 116,383 crude ounces (3,619,919 g) for 1997 (Fig. 1). This represents an approximate 22% drop in production. This gold is worth approximately CDN$31.4 million which is CDN$12 million lower than the value of gold produced in 1997.

Mining Land Use regulations are scheduled to take effect on placer claims in 1999 and the current standards of effluent discharge set out in the Yukon Placer Authorization will be reviewed in 2001. These are some of the issues that face the industry, along with the lowest placer gold production in 16 years. However, the number of active mining operations has dropped only 6%, which is evidence that these mainly family-run businesses are committed to remaining in the Yukon, and they continue to significantly contribute to the Yukon economy as they have for last 100 years.

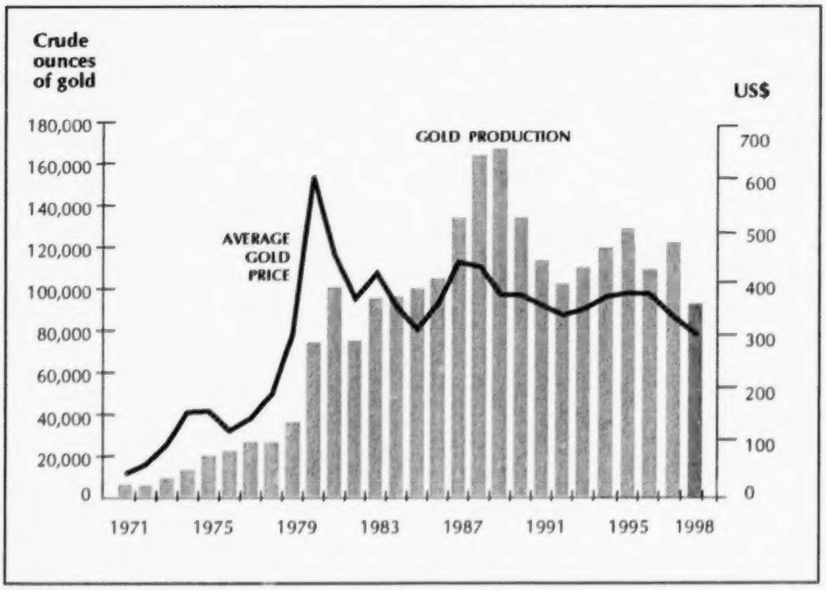


Figure 1. *Yearly gold production figures for the Yukon.*

RÉSUMÉ

Les faibles prix de l'or ont continué à décourager l'industrie de l'exploitation minière des placers au Yukon en 1998 pour entraîner des diminutions de la production ainsi que de l'emploi dans ce secteur. De nombreuses exploitations on a été contraintes à réduire leurs activités, résultant en coupures de personnel et entraînant un régime à un quart de travail plutôt que deux. Dans d'autres exploitations disposant de permis d'exploitation hydraulique il n'y a eu aucune extraction et on s'est contenté d'exécuter des travaux d'exploration ou d'entretien d'équipement. Dans plusieurs exploitations on a exploité de manière sélective uniquement les zones à forte teneur, préférant laisser de côté les zones moins rentables pour des jours où le cours de l'or se sera amélioré.

Il y avait au total 161 mines en exploitation et l'industrie assurait des emplois directs à environ 600 personnes, ce qui représente une diminution de 20 % au niveau de l'emploi et de 6 % en termes du nombre d'exploitations par rapport à 1997. Plus de 80 % de l'or placérien a été tiré des régions non glaciaires du Yukon, notamment les régions du Klondike, d'Indian River, de l'ouest du Yukon (Fortymile, Sixtymile, Moosehorn) et de la basse rivière Stewart. Le reste de l'or provenait des régions glaciaires dont celles du Clear Creek, de Mayo, de la chaîne Dawson, de Kluane et du ruisseau Livingstone.

À la fin de septembre, la production d'or pour 1998 totalisait 71 718 onces (2 230 681 g) d'or brut comparativement à 96 735 onces (3 008 797 g) pour la même période en 1997. Cela représente une diminution de la production d'environ 27 % et correspondrait à une production estimée d'environ 85 000 onces (2 643 798 g) à la fin de 1998. Cet or vaut approximativement 30 millions de dollars canadiens, soit 12 millions de moins que la valeur de la production d'or en 1997.

Le règlement sur l'utilisation des terres pour l'exploitation de placers au Yukon doit entrer en vigueur en 1999 et les normes en matière de déversement d'effluents actuellement établies dans le Yukon Placer Authorization seront réexaminées en 2001. Ce sont quelques-uns des problèmes avec lesquels doit composer l'industrie qui a fourni la plus faible production d'or placérien en 16 ans. Le nombre des exploitations en activité n'a toutefois diminué que de 6 %, ce qui constitue une indication du fait que ces entreprises principalement familiales sont engagées à rester au Yukon et elles continuent à contribuer de manière importante à l'économie du territoire comme elle l'ont fait au cours des 100 dernières années.

L'histoire quaternaire et la géochimie du till du district d'Anvil de la partie centrale est du Yukon

GOVERNMENT

Yukon Geology Program

Grant Abbott
Yukon Geology Program

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Yukon Geology Program

Grant Abbott
Yukon Geology Program

Abbott, J.G. 1999. Yukon Geology Program. *In:* Yukon Exploration and Geology 1998, C.F. Roots and D.S. Emond (eds.); Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 35-44.

OVERVIEW

Now in its third year, the Yukon Geology Program (Fig. 1) is a *de facto* Yukon Geological Survey consisting of two integrated and jointly managed offices with different administrative structures (Fig. 2). Federal funding is provided through the Exploration and Geological Services Division of the Department of Indian Affairs and Northern Development (DIAND), and territorial and cost-shared (YTG/DIAND) funding comes through the Mineral Resources Branch of the Department of Economic Development (Yukon Government, YTG). The Geological Survey of Canada (GSC) also maintains an office with the Program.

Figure 1. *Top row, from left: Jason Adams, Charlie Roots, Tammy Allen, Will van Randen.*
Bottom; standing, from left: Gord Nevin,Diane Emond, Grant Lowey, Jo-Anne van Randen, Lee Pigage, Maurice Colpron, Shirley Abercrombie, Danièle Héon, Ali Wagner (front), Panya Lipovsky (back), Kaori Torigai, Jeff Bond, Grant Abbott, Julie Hunt (back), Lisabeth Bryan (front), Robert Deklerk (back), Bill LeBarge (front), Mike Burke, Don Murphy, Craig Hart.

The past year saw some stability and growth after the uncertainty and change of the previous year. Five managers completed their first full year in new jobs. In DIAND, they were: Terry Sewell, Regional Director General; Bob Holmes, Director, Mineral Resources Directorate; and Grant Abbott, Acting Chief Geologist, Exploration and Geological Services Division. In YTG they were: Jesse Duke, Acting Director, Mineral Resources Branch and Shirley Abercrombie, Acting Manager, Mineral Resources Branch. Five geological positions were filled. Lee Pigage and Maurice Colpron will undertake regional mapping, Jeff Bond is in a term position to undertake till geochemical surveys, Jo-Anne van Randen is also in a term position as a resource assessment geologist, and Gord Nevin is our GIS technician. The Program is now operating at full strength for the first time in three years.

Negotiations to devolve the responsibilities of the Northern Affairs Program to YTG are ongoing. Conclusion of negotiations on outstanding issues is expected before release of this publication. If they are successful, transfer could be completed as early as the end of 1999, a year later than originally planned.

PROGRAM HIGHLIGHTS FOR 1998

The Yukon Geology Program (YGP) in 1998 supported three regional bedrock mapping projects, two mineral deposit studies, two placer deposit studies, a till geochemistry study, two staff geologists, one Yukon Minfile geologist, two resource assessment geologists, and one GSC mapper. Several other projects were also funded through contributions to the Geological Survey of Canada and to university researchers. Figure 3 is a summary of available geological maps and regional geochemical and geophysical maps from the Yukon Geology Program.

FIELDWORK

Recent massive sulphide discoveries in the Finlayson Lake District have helped to stimulate research interest in the Yukon-Tanana Terrane and other pericratonic terranes in the northern Cordillera. The Yukon Geology Program is playing a significant role in the Ancient Pacific Margin NATMAP proposal. This

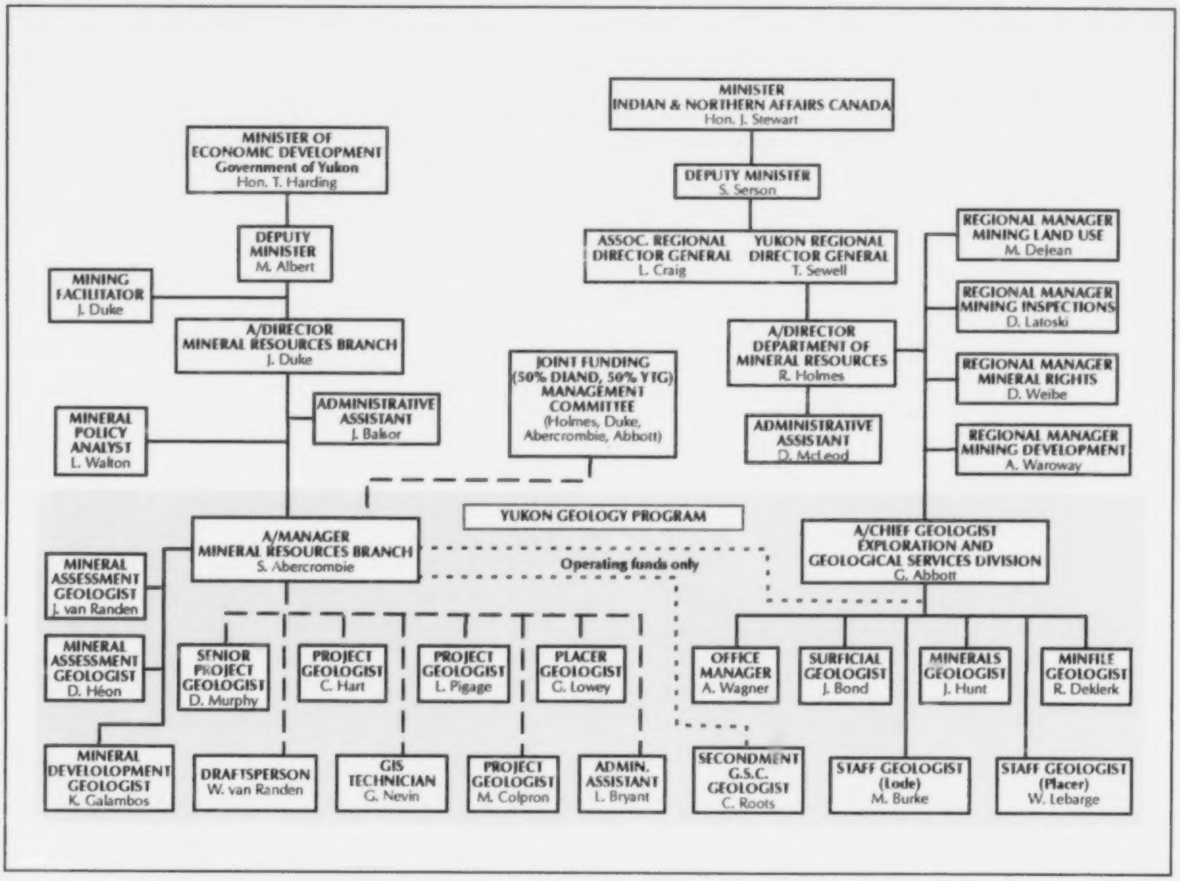
MINISTER INDIAN & NORTHERN AFFAIRS CANADA Hon. J. Stewart
MINISTER OF ECONOMIC DEVELOPMENT Government of Yukon Hon. T. Harding
DEPUTY MINISTER S. Serson
DEPUTY MINISTER M. Albert
ASSOC. REGIONAL DIRECTOR GENERAL L. Craig
YUKON REGIONAL DIRECTOR GENERAL T. Sewell
REGIONAL MANAGER MINING LAND USE M. Dejean
MINING FACILITATOR J. Duke
REGIONAL MANAGER MINING INSPECTIONS D. Latoski
A/DIRECTOR MINERAL RESOURCES BRANCH J. Duke
JOINT FUNDING (50% DIAND, 50% YTG) MANAGEMENT COMMITTEE (Holmes, Duke, Abercrombie, Abbott)
A/DIRECTOR DEPARTMENT OF MINERAL RESOURCES R. Holmes
REGIONAL MANAGER MINERAL RIGHTS D. Weibe
MINERAL POLICY ANALYST L. Walton
ADMINISTRATIVE ASSISTANT J. Balsor
ADMINISTRATIVE ASSISTANT D. McLeod
REGIONAL MANAGER MINING DEVELOPMENT A. Waroway
YUKON GEOLOGY PROGRAM
A/MANAGER MINERAL RESOURCES BRANCH S. Abercrombie
Operating funds only
A/CHIEF GEOLOGIST EXPLORATION AND GEOLOGICAL SERVICES DIVISION G. Abbott
MINERAL ASSESSMENT GEOLOGIST J. van Randen
MINERAL ASSESSMENT GEOLOGIST D. Héon
SENIOR PROJECT GEOLOGIST D. Murphy
PROJECT GEOLOGIST C. Hart
PROJECT GEOLOGIST L. Pigage
PLACER GEOLOGIST G. Lowey
OFFICE MANAGER A. Wagner
SURFICIAL GEOLOGIST J. Bond
MINERALS GEOLOGIST J. Hunt
MINFILE GEOLOGIST R. Deklerk
MINERAL DEVELOLOPMENT GEOLOGIST K. Galambos
DRAFTSPERSON W. van Randen
GIS TECHNICIAN G. Nevin
PROJECT GEOLOGIST M. Colpron
ADMIN. ASSISTANT L. Bryant
SECONDMENT G.S.C. GEOLOGIST C. Roots
STAFF GEOLOGIST (Lode) M. Burke
STAFF GEOLOGIST (Placer) W. Lebarge

Figure 2. *Yukon Mineral Resources organization chart.*

cooperative effort involves the Geological Survey of Canada, the British Columbia Geological Survey (BCGS) and the universities of Alberta, British Columbia and Victoria. The project, if approved, will examine critical localities in British Columbia, Yukon and possibly Alaska. The Yukon Geology Program will continue mapping by Don Murphy in the Finlayson Lake area, and by Maurice Colpron in the Glenlyon area. In the Stewart River area, where most of the Yukon's placer gold deposits are located, placer deposit studies by Grant Lowey will accompany surficial mapping by Lionel Jackson of the GSC. The Geological Survey of Canada contribution will include Steve Gordey in the Stewart River map area, Charlie Roots in the western half of Wolf Lake map area, and in the northern half of Jennings River map area with Joanne Nelson and Mitch Mihalynuk of the BCGS.

The closure of the Faro mine at the beginning of the year was a major blow to the Yukon economy. Remaining reserves in the Anvil District are uneconomic at present, but significant exploration potential remains. The YGP has embarked on several projects to capture, synthesize, and enhance the geological database that owners of the mine have accumulated over the last 30 years. Lee Pigage who has 20 years of mapping and exploration experience in the district is overseeing the project, and has begun compilation and bedrock mapping at 1:25 000 scale. Lithogeochemical studies by Cliff Stanley of Acadia University will test reports by exploration geologists of visual alteration of host rocks above the Grizzly (formerly Dy) deposit. The study could define a new exploration tool for the district. Jeff Bond is mapping the surficial geology of the district and has completed a case study of till geochemistry down-ice from the Faro deposit.

Placer deposit studies were also a main focus. After completing a compilation map of the geology of the White Channel gravels in the Klondike district, Grant Lowey began studies of placer deposits in the Stewart River map area. This project will be part of the proposed Ancient Pacific Margin NATMAP project. In partnership with the Mining Inspections Division of the Northern Affairs Program, Bill LeBarge and Mark Nowosad from Okanagan College began a new project to study the relationship between sedimentology, grain size distribution, and water quality of effluent from placer deposits. Data gathered from this study should assist with the review of the Yukon Placer Authorization, scheduled for 2001.

Julie Hunt is in the final year of her study of volcanogenic massive sulphide deposits (VMS). Her focus was the geological setting of the Wolf deposit, in Devono-Mississipian volcanic rocks on the Pelly Cassiar Platform. The Wolf deposit is a new discovery which has re-ignited exploration interest in the rocks of Ancient North America after so much recent attention was paid to VMS deposits of similar age in adjacent Yukon-Tanana terrane.

Craig Hart postponed a good part of the third year of his metallogenic study of the Dawson Range. Forest fires and a shortage of helicopters forced him to change course and focus on precious metal occurrences related to the Tombstone suite of Cretaceous intrusions. These include the Brewery Creek gold deposit and in Alaska, the Fort Knox and True North gold deposits. In the Dawson Range, Craig has not only the task of putting the wide variety of intrusion-related precious and base-metal deposits into their regional context, but is also compiling new 1:50 000 scale geology maps based on interpretation of geophysical surveys that were funded by the 1990-1996 Canada-Yukon Economic Development Agreement. Interest in the Dawson Range may be spurred next year by the recent realization that several of the gold occurrences and deposits in it are the same age as the exciting new Pogo gold discovery on trend to the west in Alaska.

OTHER PROJECTS

The Yukon Geology Program supported the work of several scientists of the Geological Survey of Canada. Charlie Roots is nearing completion of a final report for Lansing map area. This will be the completion of a seven-year-long project to map Mayo and Lansing map areas. Steve Gordey is completing the compilation of a digital geological map of the Yukon. The map is expected to be released on CD-ROM in March, 1999 and will be a significant step forward in our efforts to produce digital products and to manage the large amount of geological information now available in the Yukon. Alejandra Duk-Rodkin received support to produce a glacial limits map of the Yukon to mark the centennial of the Klondike Gold Rush in 1998. Part of this project has resulted in a significant reinterpretation of the early glacial history of Stewart River map area which will lead to a much better understanding of the remaining placer potential there. The glacial limits map will be integrated with the digital bedrock compilation.

INDUSTRY LIAISON AND SUPPORT

Mike Burke and Bill LeBarge, our main links to the exploration industry, continued to monitor Yukon hard rock and placer mining and mineral exploration activity, visit active properties, review reports for assessment credit, and maintain the assessment report library.

YUKON MINFILE

Yukon MINFILE, the Yukon's inventory of mineral occurrences, and another mainstay of the Yukon Geology Program, is maintained by Robert Deklerk. We have completed an upgrade from Foxbase to Microsoft Access Version 2 and are now proceeding with an upgrade to Access 97 with major revision and simplification of the database structure. Paper copies of the text version are available through Exploration and Geological Services Division, and the updated digital version will be released on CD-ROM this spring and sold by Hyperborean Productions in Whitehorse.

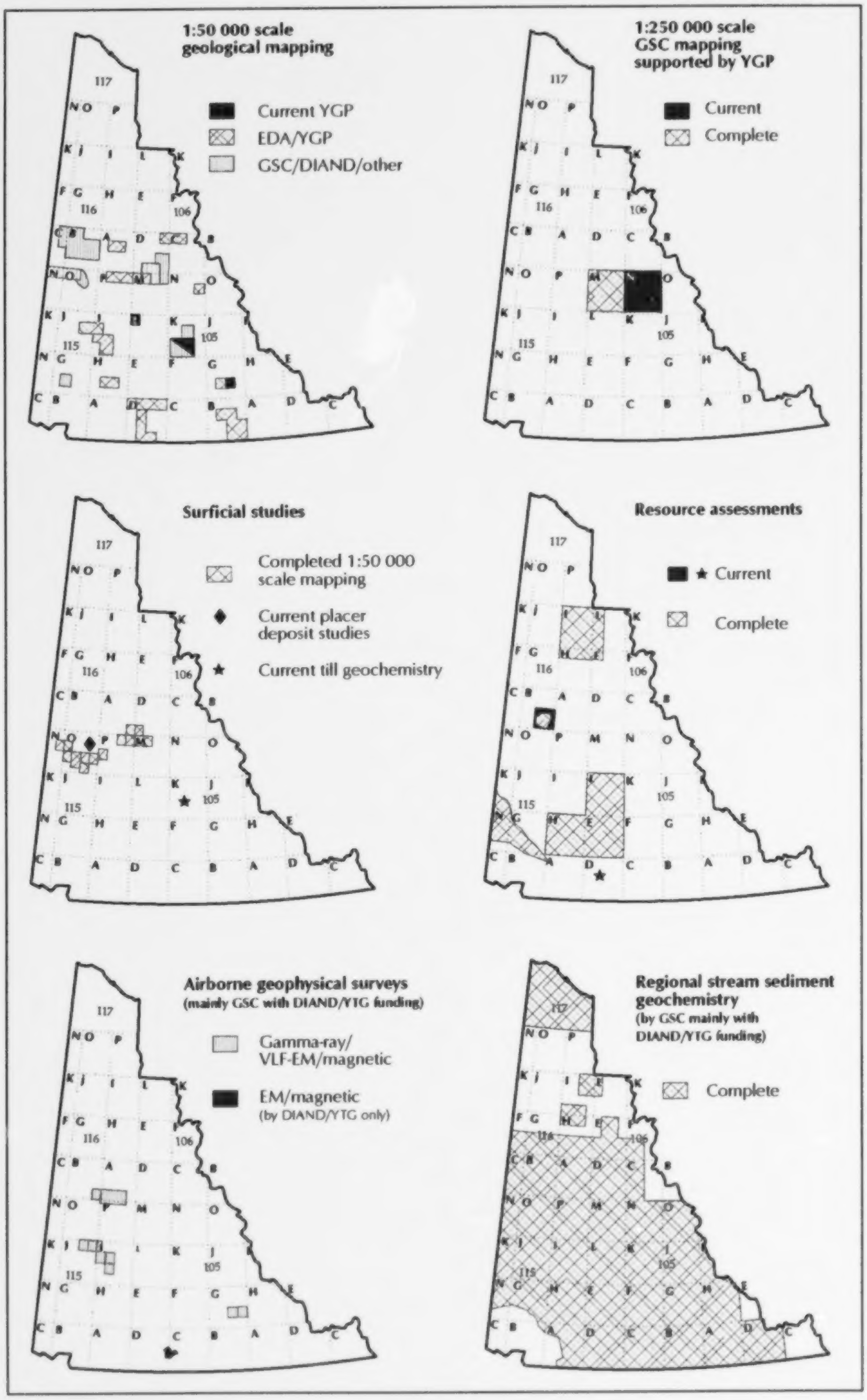
1:50 000 scale geological mapping
Current YGP
EDA/YGP
GSC/DIAND/other
1:250 000 scale GSC mapping supported by YGP
Current
Complete
Surficial studies
Completed 1:50 000 scale mapping
Current placer deposit studies
Current till geochemistry
Resource assessments
Current
Complete
Airborne geophysical surveys (mainly GSC with DIAND/YTG funding)
Gamma-ray/ VLF-EM/magnetic
EM/magnetic (by DIAND/YTG only)
Regional stream sediment geochemistry (by GSC mainly with DIAND/YTG funding)
Complete
117
116
106
115
105

Figure 3. *Summary of available geological maps and regional geochemical surveys in the Yukon. Not shown are 1:250 000 scale geological maps and regional aeromagnetic maps which cover most of the Territory, and are published by the Geological Survey of Canada.*

YUKON GEOPROCESS FILE

The Yukon Geoprocess File, under the direction of Diane Emond, is an inventory of information on geological process and terrain hazards, and also includes references and summaries of bedrock and surficial geology. The Geoprocess File is intended as a planning aid for development activities and is available for most areas south of 66° latitude.

H.S. BOSTOCK CORE LIBRARY

The H.S. Bostock Core library is maintained by Robert Deklerk. The facility contains about 128,000 m of diamond drill core from about 200 Yukon mineral occurrences. Confidentiality of material is determined on the same basis as mineral assessment reports. Confidential core can be viewed with a letter of release from the owner. Rocks saws and other rock preparation equipment are available to the public.

MINERAL RESOURCE ASSESSMENTS

The Yukon Geology Program is responding to an increasing need for geological and metallogical information to assist resolution of land use issues and conflicts. Some of the pressures have come from native land claims negotiations, and localized land use conflicts such as one within the city limits of Whitehorse, but most important is the priority of the Yukon government to implement a Protected Areas Strategy by the year 2000. The Yukon Protected Area Strategy will result in protection and withdrawal of land in all 23 ecoregions in the Yukon. YTG plans to provide efficient and cost-effective input into the selection process by undertaking a Yukon-wide mineral potential study under the direction of Danièle Héon in the spring of 1999.

YUKON MINING INCENTIVE PROGRAM

The Yukon Government provides grants for grassroots exploration and initial development of properties. This year, under the supervision of Ken Galambos, $378,000 was distributed to 27 prospectors.

PUBLICATIONS

The Yukon Geology Program is now converted to fully digital publishing. All geological maps are now printed, and new publications are being produced, from a digital format, on-demand. This advance will greatly reduce our printing and storage costs. We expect to eventually sell digital files through our website.

Appendix 1 is a summary of recent references including Yukon Geology Program publications and maps, articles in outside journals, theses and other Yukon publications of interest.

Yukon Geology Program publications are published by Exploration and Geological Services Division, DIAND and are available through:

Geoscience Information and Sales
c/o Whitehorse Mining Recorder
102-300 Main Street
Whitehorse, Yukon Y1A 2B5
Phone (867) 667-3266, Fax. (867) 667-3267

To learn more about the Yukon Geology Program, visit our homepage at
http://www.yukonweb.com/government/geoscience/
or contact us directly:

Grant Abbott, Acting Chief Geologist
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Indian and Northern Affairs Canada
345-300 Main Street
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Shirley Abercrombie, Acting Manager
Mineral Resources Branch
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Government of Yukon
Box 2703
Whitehorse, Yukon Y1A 2C6
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RÉSUMÉ

Le Programme d'études géologiques du Yukon est un programme intégré réalisé à frais partagés par la Division de l'exploration et des services géologiques des Affaires indiennes et du Nord Canada (MAINC), la Division des ressources minérales du gouvernement du Yukon et la Commission géologique du Canada de Ressources naturelles Canada. Nous recueillons, compilons et communiquons des informations sur la géologie et les gisements de minéraux au Yukon.

Notre principale activité est de dresser des cartes géologiques, qui sont essentielles à la prospection, aux recherches géologiques et à la planification de l'utilisation des terres. Depuis 1991, nous avons produit vingt cartes sur le substratum rocheux à l'échelle de 1/50 000. Plus tard au cours de l'année, les données cartographiques numeriques que compile actuellement à l'échelle de 1/250 000 la Commission géologique du Canada, seront diffusées.

La cartographie des dépôts superficiels en appui à l'exploitation des placers est également une priorité. Pendant l'année, des projets de cartographie, de compilation et d'évaluation de placers ont continuée, soit :

1) le projet de recherche sur le placer Mayo; et

2) les études sur le placer de la région Rivière Stewart. Une nouvelle carte des limites glaciaires est en outre en cours de production en collaboration avec la Commission géologique pour commémorer le centenaire de la ruée vers l'or.

Deux études géologiques spécifiques ont été amorcées :

1) une sur les gisements de sulfures massifs volcanogènes dans le terrane Yukon-Tanana, la plate-forme de Pelly-Cassiar et le bassin de Selwyn; et

2) une autre sur les gisements de métaux précieux et communs dans le chaînon Dawson.

Des études sur le potentiel minéral sont entreprises au besoin (p. ex. associées aux revendications territoriales des Premières Nations, aux parcs, etc.). Elles permettent de donner aux décideurs une évaluation actuelle du potentiel minéral de façon à ce que le retrait des terres soit fondé sur des informations les plus exhaustives possibles.

Les données géochimiques et géophysiques recueillies au Yukon peuvent être obtenues en s'adressant à la Commission géologique du Canada. Des données géochimiques sur les sédiments fluviatiles et l'eau à l'échelle régionale ont été recueillies dans presque tout le territoire. Des levés géophysiques multiparamétriques aériens ont été réalisés dans les régions du chaînon Dawson, des monts Tombstone et du lac Finlayson.

Le Programme d'études géologiques du Yukon consiste à diriger des activités d'exploration minérale et entretient des rapports étroits avec l'industrie minérale. Nous gérons la base de données Minfile sur le Yukon ainsi que la compilation de données géologiques et historiques sur toutes les occurrences minérales connues du Yukon, qui s'élèvent à plus de 2 500. Le fichier de Minfile sur les placers est en cours d'élaboration et sera diffusé plus tard au cours de l'année. Le fichier GEOPROCESS du Yukon est un résumé de la géologie, des processus géologiques et des dangers liés au terrain. Nous produisons également deux publications annuelles: Yukon Exploration and Geology et Yukon Placer Activity. La carothèque H.S. Bostock contient quelque 128 000 m de carottes extraites à la foreuse au diamant dans 200 propriétés minières au Yukon.

Le Programme d'incitatifs à l'exploitation minière du Yukon, mis sur pied par le gouvernement du Yukon, appuie financièrement les prospecteurs (< 10 000 $ par année) et les sociétés d'exploration (< 20 000 $ par année) dans le but de promouvoir la prospection, l'exploration minérale et la mise en valeur minière au Yukon.

Pour en savoir plus long sur le Programme d'études géologiques du Yukon, visitez notre page d'accueil à *http://www.yukonweb.com/government/geoscience/* ou communiquez directement avec :

Grant Abbott, Géologue principal intérimaire
Division de l'exploration et des services géologiques
Affaires indiennes et du Nord canadien
300 rue Main-bur.345
Whitehorse (Yukon) Y1A 2B5
Téléphone : (867) 667-3200, Courriel : abbottg@inac.gc.ca

Shirley Abercrombie, Gestionnaire intérimaire
Division des ressources minérales
Ministère de l'expansion économique
C.P. 2703
Whitehorse (Yukon) Y1A 2C6
Téléphone : (867) 667-3438, Courriel : sabercro@gov.yk.ca

On peut obtenir des exemplaires des publications du Programme d'études géologiques du Yukon en s'adressant à :

Bureau d'information et des ventes en géosciences
a/s Conservateur des registres miniers
Affaires indiennes et du Nord canadien
300 rue Main-bur.102
Whitehorse (Yukon) Y1A 2B5
Téléphone : (867) 667-3266

APPENDIX 1: RECENT PUBLICATIONS

GEOSCIENCE MAPS

Geoscience Map 1998-1: Surficial geology of Sprague Creek map area, central Yukon (115P/15; 1:50 000 scale), by Jeffrey Bond.

Geoscience Map 1998-2: Surficial geology of Seattle Creek map area, central Yukon (115P/16; 1:50 000 scale), by Jeffrey Bond.

Geoscience Map 1998-3: Surficial geology of Mount Haldane map area, central Yukon (105M/13; 1:50 000 scale), by Jeffrey Bond.

Geoscience Map 1998-4: Surficial geology of Keno Hill map area, central Yukon (105M/14; 1:50 000 scale), by Jeffrey Bond.

Geoscience Map 1998-5: Surficial geology of North McQuesten River map area, central Yukon (115A/1; 1:50 000 scale), by Jeffrey Bond.

Geoscience Map 1998-6: Surficial Geology of Dublin Gulch map area, central Yukon (106D/4; 1:50 000 scale), by Jeffrey Bond.

Geoscience Map 1998-7: Surficial Geology of Matson Creek and Ogilvie (115N/9 and 115O/12; 1:50 000 scale to accompany O.F. 1998-1), by C. Mougeot and L. Walton.

Geoscience Map 1998-8: Surficial Geology of Garner Creek (115O/13; 1:50 000 scale to accompany O.F. 1998-1) by C. Mougeot and S. Morison.

Geoscience Map 1998-9: Geological map of Slats Creek area, Wernecke Mountains, Yukon (106D/16; 1:50 000 scale), by Derek J. Thorkelson.

Geoscience Map 1998-10: Geological map of Fairchild Lake area, Wernecke Mountains, Yukon (106C/13; 1:50 000 scale), by Derek J. Thorkelson.

Geoscience Map 1998-11: Geological map of Dolores Creek area, Wernecke Mountains, Yukon (106C/14; 1:50 000 scale), by Derek J. Thorkelson.

OPEN FILES

Open File 1998-1: Surficial geology and sedimentology of Garner Creek, Ogilvie, and Matson Creek map areas (115O/13, 115O/12 and 115N/9, east half), by Stephen Morison with contributions from Lori Walton and Charlotte Mougeot (includes Geoscience Maps 1998-7,8).

Open File 1998-2. White Channel Gravel, Klondike Gold Fields, Yukon, Canada, by G.W. Lowey (Poster available in French and English).

Open File 1998-3. Preliminary geological map, Little Kalzas Lake, central Yukon (105L/13; 1:50 000 scale), by Maurice Colpron.

Open File 1998-4. Preliminary geological map of Wolverine Lake area, Pelly Mountains, southeastern Yukon (105G/8, north half; 1:50 000 scale), by Donald C. Murphy and Steve Piercey.

Open File 1998-5: Preliminary geological map of the Mount Vermilion area, southern Yukon (parts of 105G/5 and 105G/6; 1:25 000 scale), by J.A. Hunt.

OUTSIDE ARTICLES

Hunt, J.A., 1998. Recent discoveries of volcanic-associated massive sulphide deposits in the Yukon. CIM Bulletin, vol. 91, No. 1017.

Lowey, G. W., 1998. A new estimate of the amount of displacement on the Denali Fault system based on the occurrence of carbonate megaboulders in the Dezadeash Formation (Jura-Cretaceous), Yukon, and the Nutzotin Mountains sequence (Jura-Cretaceous), Alaska. Bulletin of Canadian Petroleum Geology, vol. 46, no. 3, p. 379-386.

Miller, L.D., Goldfarb, R.J., Nie, F.J., Hart, C.J.R., Miller, M.L., Yueqing Yang, Y. and Liu, Y., 1998. North China Gold: A product of multiple orogens. Society of Economic Geologists Newsletter, No. 33, p. 1-12.

Wynne, P.J., Enkin. R.J., Baker, J., Johnston, S.T. and Hart, C.J.R., 1998. The Big Flush – Paleomagnetic signature of a 70 Ma regional hydrothermal event in displaced rocks of the northern Canadian Cordillera. Canadian Journal of Earth Sciences, vol. 35, p. 657-671.

ABSTRACTS

Enkin. R.J., Wynne, P.J., Baker, J., Johnston, S.T. and Hart, C.J.R., 1998. The Big Flush – Paleomagnetic signature of a 70 Ma regional hydrothermal event in displaced rocks of the northern Canadian Cordillera. LITHOPROBE Snorcle Report 64.

Harris, M.J., Symons, D.T.A., Blackburn, W.H. and Hart, C.J.R., 1998. The northern Canadian Cordillera: paleomagnetic evidence for NAFTA. Geological Society of America Programs with Abstract, vol. 30, No. 7, p. A355.

Harris, M.J., Symons, D.T.A., Blackburn, W.H. and Hart, C.J.R., 1998. Late Cretaceous tectonic motions "North of 60°": Paleomagnetic evidence from the Mount Lorne Stock, Yukon. EOS, vol. 79, AGU Spring meeting, Boston, Mass., p. S63.

Harris M.J., Symons, D.T.A., Blackburn, W.H. and Hart, C.J.R., 1998. Late Cretaceous-Eocene motion of the Stikine terrane: Paleomagnetic evidence from the 75 Ma Mount Lorne Stock, Yukon, Canada. EOS, vol. 79, AGU Fall meeting, San Francisco, p. F220.

Harris, M.J., Symons, D.T.A., Blackburn, W.H. and Hart, C.J.R., 1998. Jurassic motions of the Canadian Cordillera: Paleomagnetic evidence from the Guichon Batholith, B.C. and the Teslin Stock, Y.T. GAC/MAC Program and Abstracts, vol. 23, Quebec City, p. A73.

Harris, M.J., Symons, D.T.A., Hart, C.J.R. and Blackburn, W.H., 1998. An Early Eocene end for northward displacement of the Coast Plutonic Complex in northern Canada and Alaska, from paleomagnetism. GAC/MAC Program and Abstracts, vol. 23, p. A73, Quebec City.

Harris, M.J., Symons, D.T.A., Blackburn, W.H. and Hart, C.J.R., 1997. Tectonic motion of the Jurassic Fourth of July Batholith, northern British Columbia, from paleomagnetism. EOS, vol. 78, AGU Fall meeting, Abstracts and Program, San Francisco, p. F188.

Harris, M.J., Symons, D.T.A. and Hart, C.J.R., 1997. Regional conglomerate test for orogenic remagnetization of plutons in the northern Cordillera of Canada. Eighth Scientific Assembly, International Association of Geomagnetism and Aeronomy, Abstracts. Uppsala, Sweden, p. 74.

Hart, C.J.R., Harris, M.J., Blackburn, W.H. and Symons, D.T.A., 1998. Depth of skarn formation as determined by Al-in-amphibole geobarometry, Whitehorse Copper Belt. Geological Association of Canada/MAC Program and Abstracts, vol. 23, Quebec City, p. A74.

Hart, C.J.R., Johnston, S.T., Francis, D., Smuk, K., Wynne, P.J. and Enkin. R.J., 1998. Yellowstone in Yukon: a hotspot link to Late Cretaceous alkalic-associated Cu-Au mineralization. *In:* Cordillera Revisited: Recent Developments in Cordilleran Geology, Tectonics and Mineral Deposits, Short Course Extended Abstracts, Exploration Methods '98-Pathways to Discovery, Geological Association of Canada, Cordilleran Section, p. 110-117.

Hart, C.J.R., Villeneuve, M. and Thorkelson, D.J., 1998. Geochronology and tectonic origin of Neogene alkalic volcanic rocks in the northern Canadian Cordillera. Geological Society of America Programs with Abstract, vol. 30, No. 7, p. A242.

LeBarge, W.P., 1998. Placer deposit models in glaciated terrain: examples from ice marginal settings in central Yukon. *In:* Main Results of the Study of the Quaternary Period and Principal Directions of Research in the XXI Century, Abstracts presented at the All-Russian Meeting of the Quaternary Investigations, St. Petersburg, Russia, September 14-19, 1998, p. 302.

LeBarge, W.P., 1997. Geological setting, production and exploration potential of Yukon placer gold deposits, *In:* Major Geological and Commercial Types of Placers and Weathered Rock Mineral Deposits, Technology of Estimation and Development, Abstracts presented at the XIth Symposium on Mineral Deposits Associated with Placers and Weathered Rocks, Moscow, Russia, September 15-19, 1997, p. 114.

McCausland P.J.A., Symons, D.T.A. and Hart, C.J.R., 1998. Post-Cretaceous geotectonic motion of the Yukon-Tanana Terrane from paleomagnetism of the Seymour Creek stock, Yukon Territory. EOS, vol. 79, AGU Fall meeting, San Francisco. F219-F220.

Murphy, D., 1998. Mafic and ultramafic plutonic rocks south of Finlayson Lake, Yukon: setting and implications for the early geological and metallogenic evolution of the Yukon-Tanana Terrane. Lithoprobe Report No. 64, p.120-129.

Symons, D.T.A., Harris, M.J., Hart, C.J.R. and Blackburn, W.H., 1998. Geotectonics in the northern Cordillera from paleomagnetism and geobarometry: Progress report and recent results from the Eocene White Pass dikes and Jurassic Fourth of July batholith. Lithoprobe Report 64, p. 171-180.

Symons, D.T.A., Harris, M.J., Blackburn, W.H. and Hart, C.J.R., 1997. Paleomagnetic and geobarometric study of the Teslin Crossing Stock, Stikine Terrane, Yukon, Canada. EOS, vol. 78, AGU Fall meeting, Abstracts and Program, San Francisco, p. F189.

Symons, D.T.A., Harris, M.J., Hart, C.J.R. and Blackburn, W.H., 1998. Paleomagnetism of the Eocene White Pass dikes: End of northward translation for the accreted terranes inboard of the Cost shear zone. EOS, vol. 79, AGU Spring meeting, Boston, Mass., p. S63.

Symons, D.T.A., Williams, P.R., Hart, C.J.R., 1998. Whence came the Yukon-Tanana Terrane?: Paleomagnetism of the Jurassic Big Creek Batholith, Y.T. EOS, vol. 79, AGU Fall meeting, San Francisco, p. F222.

Thorkelson, D., J.G. Abbott, J. Mortenson, R. Creaser and M. Villeneuve, 1998. Proterozoic sedimentation, magmatism, metasomatism and deformation in the Wernecke and Ogilvie Mountains, Yukon. Lithoprobe Report No. 64, p. 110-119.

GEOLOGICAL SURVEY OF CANADA PUBLICATIONS WITH FUNDING FROM YGP

Open File D3685. National Geochemical Reconnaissance: Analytical data for Bi and Se in stream sediment samples from central Yukon (105M and 105N), by P.W. Friske, S.J.A.Day, C.C. Durham, M.W. McCurdy.

Open File 3607. Airborne geophysical survey, Brewery Creek area, Yukon Territory (NTS 116B/1 and parts of 116A/4, 115P/13), by R.B.K. Shives, J.M. Carson and P.B. Holman, 218 p.

YUKON THESES COMPLETED IN 1998

B.Sc.

Ryan, P.R., 1998. Measuring the geotectonic motion of the Yukon-Tanana Terrane. University of Windsor, Windsor, Ontario, 38 p.

Appel (née Meyer), V. 1998. Geological, geochronological and Pb isotopic constraints on the age and origin of the Mount Nansen epithermal Au-Ag vein deposit, Eastern Dawson Range, Yukon. University of British Columbia, 38 p.

M.Sc.

Driver, L., 1998. Petrogenesis of the Cretaceous Cassiar Batholith, Yukon-B.C., Canada: Implications for magmatism in the North American Cordilleran Interior. University of Alberta, 107 p.

Goodwin-Bell, J. S.,1997. A geochemical and Sm-Nd isotopic study of Cordilleran eclogites from the Yukon-Tanana Terrane. University of Alberta.

Kotler, E., 1998. The cryostratigraphic and isotopic characteristics of "muck" deposits, Klondike area, Yukon Territory. Carleton University, Ottawa, Ontario, 115 p.

Ph.D.

Harris, M., 1998 Geotectonic motions of northern Canadian Cordillera terranes from paleomagnetic measurements with geobarometric corrections. University of Western Ontario, London, Ontario, 206 p.

Mezger, J. E., 1997. Tectonometamorphic evolution of the Kluane metamorphic assemblage, SW Yukon: Evidence for Late Cretaceous eastward subduction of oceanic crust underneath North America. University of Alberta, 306 p.

YUKON PUBLICATIONS OF INTEREST

Burn, C.R., 1998. The response (1958-1997) of permafrost and near-surface ground temperatures to forest fire, Takhini River valley, southern Yukon Territory. Canadian Journal of Earth Sciences, vol. 35, p. 184-199.

Cecile, M.P., 1998. Geology and structure cross-section, Marmot Creek, Yukon Territory. Scale 1:50 000, latitude 63°45'-64°00', longitude 131°00'-131°30'. Geological Survey of Canada, Map 1923A.

Cecile, M.P., 1998. Geology and structure cross-section, Arrowhead Lake, Yukon Territory. Scale 1:50 000, latitude 63°30'-63°45', longitude 131°00'-131°30'. Geological Survey of Canada, Map 1943A.

Cecile, M.P., 1998. Geology and structure cross-section, Einarson Creek, Yukon Territory. Scale 1:50 000, latitude 63°45'-64°00', longitude 131°30'-132°00'. Geological Survey of Canada, Map 1944A.

Craig, D.B., Craig, J.E., Pelletier, K., Emond, D. and Copland, H., 1998. Reclamation practices and research on mineral exploration properties in the Yukon Territory, by Mining Land Use and Mining Development Divisions, Mineral Resources Directorate, DIAND, 36 p.

Dixon, J., 1998. Permian and Triassic stratigraphy of Mackenzie Delta, and the British, Barn, and Richardson mountains, Yukon and Northwest Territories. Geological Survey of Canada, Bulletin 528, 46 p.

Duncan, R.A., Russell, J.K., Hastings, N.L and Anderson, R.G., 1998. Geology, mineralogy, geochemistry and physical properties of the mid-Cretaceous Emerald Lake Pluton, southeastern Yukon (105O/11). One colour map, scale 1:10 000, one colour sheet with figures. Geological Survey of Canada, Open File 3571.

Erdmer, P., Ghent, E.D., Archibald, D.A. and Stout, M.Z., 1998. Paleozoic and Mesozoic high-pressure metamorphism at the margin of ancestral North America in central Yukon. Geological Society of America, Bulletin, vol. 110, p. 615-629.

Forbes, D.L., 1997. Coastal erosion and nearshore profile variability in the southern Beaufort Sea, Ivvavik National Park, Yukon Territory. Geological Survey of Canada, Open File 3531; 100 p.

Garzione, C.N., Patchett, P.J., Ross, G.N. and Nelson, J., 1998. Provenance of Paleozoic sedimentary rocks in the Canadian Cordilleran mioigeocline: A Nd isotopic study. Canadian Journal of Earth Sciences, vol. 35, p. 1603-1618.

Hall, K.W. and Cook, F.A., 1998. Geophysical transect of the Eagle Plains foldbelt and Richardson Mountains anticlinorium, northwestern Canada. Geological Society of America, Bulletin, vol. 110, p. 311-325.

Hansen, V.L. and Dusel-Bacon, C., 1998. Structural and kinematic evolution of the Yukon-Tanana upland tectonites, east-central Alaska: A record of late Paleozoic to Mesozoic crustal assembly. Geological Society of America, Bulletin, vol. 110, p. 211-230.

Love, D.A., Clark, A.H., Hodgson, C.J., Mortensen, J.K., Archibald, D.A. and Farrar, E., 1998. The timing of adularia-sericite-type mineralization and alunite-kaolinte-type alteration, Mount Skukum epithermal gold deposit, Yukon Territory, Canada: ^{40}Ar-^{39}Ar and U-Pb Geochronology. Economic Geology, vol. 93, p. 437-462.

Majorowicz J.A. and Morrow, D.W., 1998. Subsurface temperature and heat flow – Yukon and Northwest Territories. Geological Survey of Canada, Open File 3626, 29 p.

Morison, S.R. and Klassen, R.W., 1997. Surficial geology, Teslin, Yukon Territory. Scale 1:125 000, latitude 132°00'-134°00' N, longitude 60°00'-61°00' W, (NTS 105C). Geological Survey of Canada, Map 1891A.

Southam, G., 1998. Quantification of sulfur and phosphorus within secondary gold rims on Yukon placer gold. Geology, vol. 26, p. 339.

Shives, R.B.K., Carson, J.M., Holman, P.B., 1998. Airborne geophysical survey, Brewery Creek area, Yukon (116B/1 and parts of 116A/4, 115P/13). Geological Survey of Canada, Open File 3551, 118 p.

Shives, R.B.K., Carson, J.M., Holman, P.B., 1998. Airborne geophysical survey, Brewery Creek area, Yukon Territory (NTS 116B/1 and parts of 116A/4, 115P/13). Geological Survey of Canada, Open File 3607, 218 p.

Shives, R.B.K., Carson, J.M., Holman, P.B., 1998. Airborne geophysical survey, Grass Lakes area, Yukon (105G/7 and parts of 105G/2 and G/8). Geological Survey of Canada, Open File 3552.

White, J.M., Ager, T.A., Adam, D.P., Leopold, E.B., Liu, G., Jetté, H. and Schweger, C.E., 1998. Neogene and Quaternary selected palynological data from Yukon and adjacent Northwest Territories and Alaska. Geological Survey of Canada, Open File 3557, 43 p.

Yukon Placer Mining Industry Report 1995, 1996, 1997. Mining Inspection Division, Mineral Resources Directorate, DIAND, 173 p.

Finlayson project: Geological evolution of Yukon-Tanana Terrane and its relationship to Campbell Range belt, northern Wolverine Lake map area, southeastern Yukon

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University of British Columbia[1]

Murphy, D. and Piercey, S.J., 1999. Finlayson project: Geological evolution of Yukon-Tanana Terrane and its relationship to Campbell Range belt, northern Wolverine Lake map area, southeastern Yukon. *In:* Yukon Exploration and Geology 1998, C.F. Roots and D.S. Emond (eds.), Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 47-62.

ABSTRACT

Geological mapping in Wolverine Lake area has outlined new Yukon-Tanana Terrane stratigraphy, constrained the stratigraphic position of the Wolverine Lake volcanogenic massive sulphide (VMS) deposit, and clarified the relationship of Yukon-Tanana Terrane to the Campbell Range belt. Yukon-Tanana Terrane comprises two stratigraphic successions separated by an angular unconformity. Beneath the unconformity are polydeformed felsic and mafic meta-volcanic rocks, carbonaceous meta-clastic rocks, marble and granitic orthogneiss. The Kudz Ze Kayah VMS deposit occurs in felsic meta-volcanic rocks of this sequence. Yukon-Tanana Terrane rocks above the unconformity are deformed by only one phase of deformation and consist primarily of carbonaceous meta-clastic rocks and quartz- and feldspar-phyric felsic meta-volcanic rocks. The Wolverine VMS deposit occurs in this succession, associated with siliceous exhalite and baritic magnetite iron formation. Meta-basalt of the Campbell Range belt, included previously in Slide Mountain Terrane, overlies the upper succession of Yukon-Tanana Terrane with sharp contact. This contact has been observed at several localities and it appears depositional. There is no evidence that it is a terrane boundary fault.

RÉSUMÉ

La cartographie géologique de la région du lac Wolverine a permis l'ébauche d'une nouvelle stratigraphie pour le terrane de Yukon-Tanana (TYT), la détermination de la position stratigraphique du gîte sulphures massifs volcanogènes (SMV) Wolverine Lake et l'éclaircissement de la relation entre le TYT et la zone de la chaîne Campbell. Le TYT comprend deux successions stratigraphiques séparées par une discordance angulaire. Sous la discordance, se trouvent des roches métavolcaniques felsiques et mafiques, des roches métaclastiques carbonées, du marbre et un orthogneiss granitique. Toutes ces roches sont polydéformées. Le gîte SMV Kudz Ze Kayah se trouve dans les roches métavolcaniques felsiques de cette séquence. Les roches du TYT au-dessus de la discordance ne sont déformées que par une seule phase de déformation et consistent principalement de roches métaclastiques carbonées et de roches métavolcanofelsiques à quartz et feldspath porphyriques. Le gîte SMV Wolverine Lake se trouve dans cette succession, associé à une formation d'exhalite siliceuse et de magnétite barytinique. Le métabasalte de la zone de la chaîne Campbell, antérieurement inclus dans le terrane de Slide Mountain, recouvre la succession supérieure du TYT le long d'un contact franc. Ce contact a été observé en plusieurs endroits et semble stratigraphique. Il n'y a aucune indication à l'effet qu'il s'agisse d'une faille limitant un terrane.

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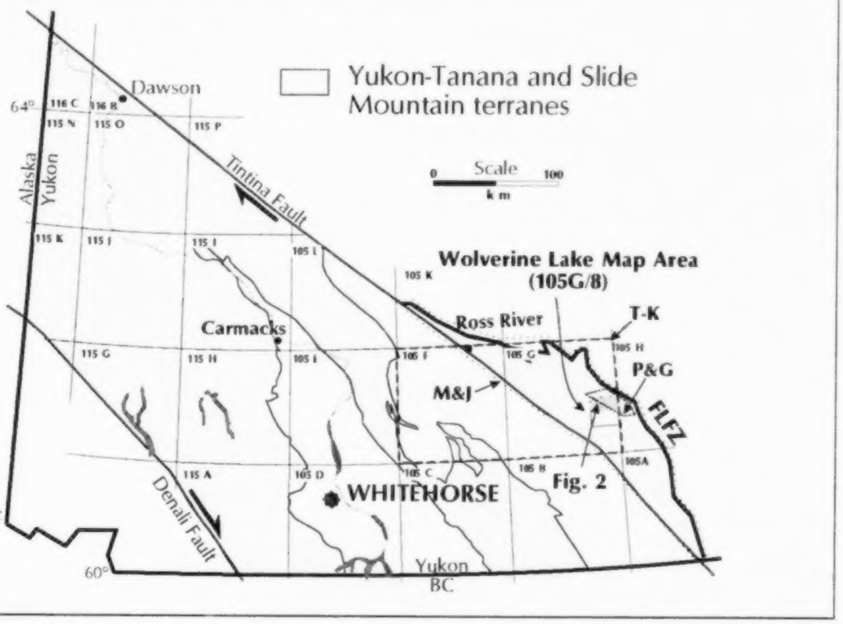
INTRODUCTION

Located south of the Campbell Highway in the heart of the Finlayson Lake massive sulphide district, Wolverine Lake map area (105G/8) is a key area in the understanding of Yukon-Tanana Terrane and the geological setting of its massive sulphide deposits (Fig. 1). The area hosts the Expatriate Resources/Atna Resources' Wolverine deposit (> 6 million tonnes at 1.33% Cu, 1.55% Pb, 12.66% Zn, 370 g/t Ag, 1.76 g/t Au; Tucker et al., 1997) and several other occurrences of massive and semi-massive sulphides. Cominco Ltd.'s Kudz Ze Kayah deposit (13 million tonnes at 1.00% Cu, 1.3% Pb, 5.5% Zn, 125 g/t Ag, 1.2 g/t Au; Schultze, 1996) lies about 5 km along strike, west of the western boundary of the map area. Mapping of Wolverine Lake area provides the opportunity to evaluate the geological setting of the Wolverine deposit and other occurrences and to compare with that of the Kudz Ze Kayah deposit in adjacent Grass Lakes map area recently mapped by Murphy (1997, 1998). More specifically, are the two deposits hosted by the same stratigraphic unit (as proposed by Hunt, 1997, 1998a,b; and Murphy, 1998)? In addition, the northern part of Wolverine Lake area is underlain by rocks of the Campbell Range belt which have been correlated with Slide Mountain Terrane (see Plint and Gordon, 1997 for a recent summary). The correlation with Slide Mountain Terrane implies that the contact of the Campbell Range succession with Yukon-Tanana Terrane is a terrane-boundary fault. Although a fault has been inferred by previous workers, this fault has not been described nor is it required by the ages of the rocks in contact. Detailed mapping in northern Wolverine Lake area provides an opportunity to examine this important contact.

In this paper and an open file map (Murphy and Piercey, 1998), we report on the results of seven weeks of geological mapping in northern Wolverine Lake map area. We conclude that Yukon-Tanana Terrane in this area comprises two stratigraphic successions separated by a previously unrecognized angular unconformity. The lower succession is made up of rocks that were deformed, metamorphosed and intruded by Early Mississippian granitic orthogneiss before the deposition of the



Yukon-Tanana and Slide Mountain terranes
Dawson
64°
116 C
116 B
115 N
115 O
115 P
Alaska
Yukon
Tintina Fault
Scale
0
100
k m
115 K
115 J
115 I
105 L
105 K
Wolverine Lake Map Area (105G/8)
Ross River
T-K
Carmacks
115 G
115 H
105 E
105 F
105 G
105 H
P&G
M&J
FLFZ
115 A
105 D
105 C
105 B
105A
Fig. 2
WHITEHORSE
Denali Fault
141°
60°
Yukon
BC

Figure 1. Location of Wolverine Lake map area with respect to the distribution of Yukon-Tanana and Slide Mountain terranes in Yukon (modified from Wheeler and McFeely, 1991). Mesozoic plutons and metamorphic complexes are not differentiated. Areas discussed by Tempelman-Kluit (1977, 1979), Mortensen and Jilson (1985) and Plint and Gordon (1997) are outlined [T-K (long dashes), M&J (dotted), P&G (short dashes), respectively]. FLFZ = Finlayson Lake fault zone

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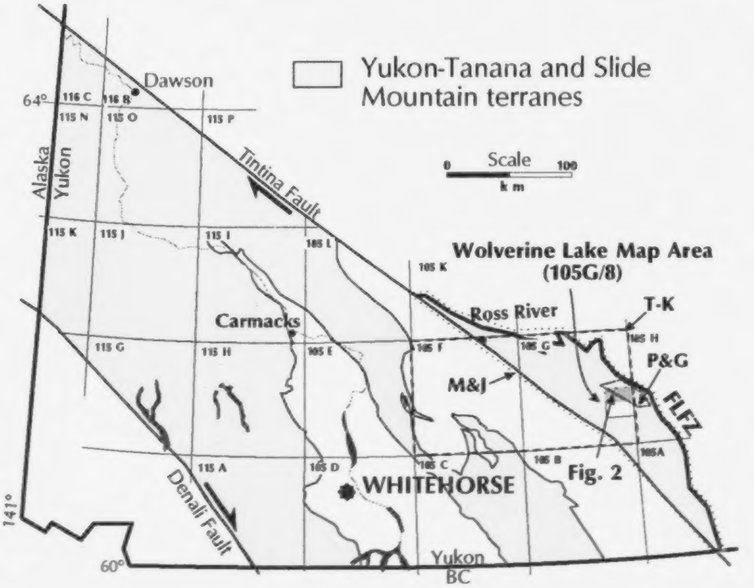
Yukon-Tanana and Slide Mountain terranes
Scale
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116 C
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Wolverine Lake Map Area (105G/8)
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upper succession. Massive sulphide deposits occur in both successions: the Kudz Ze Kayah deposit occurs in polydeformed rocks below the unconformity and the Wolverine deposit occurs in singly deformed rocks above the unconformity, hence their host units do not correlate. Secondly, in mapping the contact between the upper succession of Yukon-Tanana Terrane and Upper Paleozoic meta-basalt of the Campbell Range belt, a contact previously considered to be part of the terrane-bounding Finlayson Lake fault zone, we found no evidence of faulting and conclude that the contact is stratigraphic. It therefore cannot be a terrane boundary and Campbell Range belt must be considered in the context of the evolution of Yukon-Tanana Terrane, not as an unrelated geological element.

PREVIOUS WORK

The geology of Wolverine Lake area was initially mapped at a scale of 1"=4 mi. by Wheeler et al. (1960) and subsequently at 1:250 000 scale by Tempelman-Kluit (1977). Emphasizing the highly deformed nature of Yukon-Tanana Terrane, Tempelman-Kluit (1979) expanded this regional geological framework into a comprehensive model for the tectonic evolution of the North American continental margin. In this model, rocks of Wolverine Lake map area were included in three allochthonous sheets (siliceous cataclasite of Nisutlin Allochthon, plutonic cataclasite of Simpson Allochthon, and sheared basalt, gabbro, serpentinite of Anvil Allochthon). Nisutlin Allochthon is described by Tempelman-Kluit (1979, p. 8) as "muscovite-quartz blastomylonite and mylonite with interfoliated phyllonitic slate and chlorite schist" which grade laterally into "weakly sheared or protoclastic feldspathic quartz-granule grit and sandstone with interbedded slate" presumed to be the protolith for much of the Nisutlin Allochthon. "Dark slate and fragmental volcanics of intermediate composition" and crinoidal limestone were recognizable locally and were thought to be the protoliths for more highly sheared chlorite schist, phyllonitic slate and flaser marble. In Tempelman-Kluit's view, all original stratigraphic character and relationships were obliterated during deformation. The Nisutlin Allochthon was interpreted as tectonic mélange made up of "synorogenic clastic rocks and remnants of crustal fragments" (Tempelman-Kluit, 1979, p. 21) that were deformed and imbricated with similarly disrupted Anvil and Simpson allochthons during Early Mesozoic subduction southwestward beneath the Intermontane Belt. Rare occurrences of eclogite were offered as further evidence of a subduction zone setting for the deformation of Yukon-Tanana Terrane. The imbricated assemblage was subsequently thrust onto rocks of the outer North American continental margin in the Early Cretaceous.

In contrast to Tempelman-Kluit's "mélange" interpretation for Yukon-Tanana Terrane in this area, Mortensen (1983), Mortensen and Jilson (1985) and Mortensen (1992) recognized a stratigraphic succession and presented an alternative model for the evolution of the terrane. They subdivided the metamorphic rocks into three regionally mappable units, and in Mortensen and Jilson (1985, p. 808) described them as follows: the lower unit consists of "quartz-mica-garnet schist, micaceous feldspathic quartzite, and near the top, calcite marble and calcareous schist." The middle unit consists of "dark gray to black siliceous phyllite to quartzite, locally with medium gray calcareous phyllite toward its base" interlayered with "abundant mafic metavolcanic and lesser felsic metavolcanic rocks" and, toward the top, "abundant chloritic quartz grits, locally with bluish opalescent quartz granules." Late Devonian to mid-Mississippian U-Pb ages were obtained from felsic meta-volcanic rocks of the middle unit. The upper unit is "a package of white carbonate and quartzite that is at least in part Early Pennsylvanian to Early Permian in age [conodont ages, Tempelman-Kluit, 1979; M. Orchard, 1984, pers. comm.]" Three suites of variably deformed Devono-Mississippian granitic rocks were also recognized throughout the area, with evidence of intrusive contacts. In Mortensen and others' view, Yukon-Tanana Terrane in the Finlayson Lake area consists of a mid-Paleozoic magmatic arc, its continental crustal basement, and overlying Upper Paleozoic platformal rocks. The continental magmatic arc represented by the Permian Klondike Schist documented in Mortensen (1990, 1992) was, and is as yet, unrecognized in the Finlayson Lake area. This assemblage was initially intensely deformed and metamorphosed in the Permian or Triassic on the basis of deformed and metamorphosed clasts in nearby Norian conglomerate. Subsequently, between Late Triassic and mid-Cretaceous time, the terrane was imbricated by thrusting with the Norian clastic rocks and with meta-basalt, mafic and ultramafic meta-plutonic rock, chert and argillite of Slide Mountain Terrane (Campbell Range belt and other isolated occurrences, all previously included in Anvil Allochthon of Tempelman-Kluit, 1979; see also Mortensen, 1992). Finally, by mid-Cretaceous time, this composite entity was joined with rocks of the North American continental margin by displacement along the Finlayson Lake fault zone, a steep structure that Mortensen and Jilson (1985) inferred to be transpressive in nature (Fig. 1).

Plint (1995) and Plint and Gordon (1995, 1996, 1997) mapped part of Wolverine Lake map area in their study of the rocks of the Campbell Range belt, its relationship to Yukon-Tanana Terrane, and the implications of this relationship for the evolution of the Finlayson Lake Fault Zone. Using lithostratigraphic and chronostratigraphic arguments, they affirmed previous correlations of rocks of the Campbell Range belt with Slide Mountain Terrane. Secondly, they inferred that meta-basalt of the Campbell Range formed in a oceanic (marginal?) basin on the basis of trace element data. Thirdly, they interpreted the contacts of Campbell Range belt with both Yukon-Tanana Terrane on the west and rocks inferred to be of North American affinity on the east as oppositely vergent thrust faults. Finally, they proposed that the Finlayson Lake fault zone, rather than being a steep fault zone, is part of an originally northeast-vergent thrust system that was subsequently modified by southwest-directed thrusts and folds.

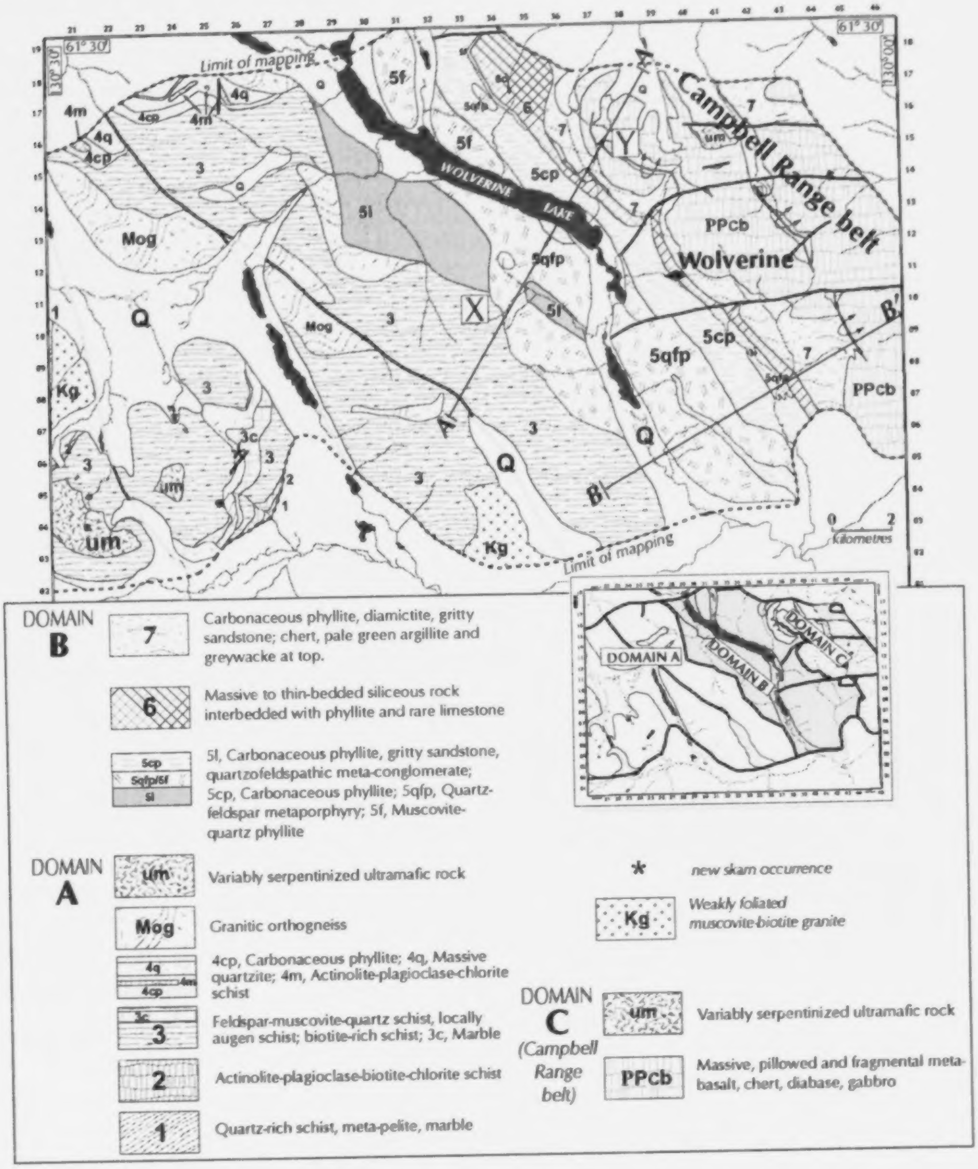
61° 30'
130° 30'
Limit of mapping
Campbell Range belt
Wolverine Lake
Wolverine
X
Y
A
A'
B
B'
Q
Kg
um
Mog
PPcb
5f
5l
5cp
5qfp
4m
4q
4cp
3
3c
2
1
6
7
0
2
Kilometres
DOMAIN A
DOMAIN B
DOMAIN C
DOMAIN B
7 Carbonaceous phyllite, diamictite, gritty sandstone; chert, pale green argillite and greywacke at top.
6 Massive to thin-bedded siliceous rock interbedded with phyllite and rare limestone
5cp 5qfp/5f 5l 5l, Carbonaceous phyllite, gritty sandstone, quartzofeldspathic meta-conglomerate; 5cp, Carbonaceous phyllite; 5qfp, Quartz-feldspar metaporphyry; 5f, Muscovite-quartz phyllite
DOMAIN A
um Variably serpentinized ultramafic rock
Mog Granitic orthogneiss
4q 4m 4cp 4cp, Carbonaceous phyllite; 4q, Massive quartzite; 4m, Actinolite-plagioclase-chlorite schist
3c 3 Feldspar-muscovite-quartz schist, locally augen schist; biotite-rich schist; 3c, Marble
2 Actinolite-plagioclase-biotite-chlorite schist
1 Quartz-rich schist, meta-pelite, marble
* new skarn occurrence
Kg Weakly foliated muscovite-biotite granite
DOMAIN C (Campbell Range belt)
um Variably serpentinized ultramafic rock
PPcb Massive, pillowed and fragmental meta-basalt, chert, diabase, gabbro

Figure 2. *Geological map of northern Wolverine Lake area. Inset map shows distribution of domains discussed in text. X and Y are locations where critical relationships between domains were observed (see text). A-A' and B-B' are lines of cross sections shown in Fig. 16.*

In the most recent phase of investigation of Yukon-Tanana Terrane in this area, the Grass Lakes area (105G/7) was mapped at 1:50 000 scale by Murphy and Timmerman (1997a,b) and Murphy (1997, 1998), and parts of neighbouring areas were mapped by Hunt and Murphy (1998). They affirmed the stratigraphically intact nature of Yukon-Tanana Terrane in this area as proposed by Mortensen and Jilson (1985) and Mortensen (1992), subdivided these authors' lower and middle units into 4 mappable units, and placed the syngenetic massive sulphide deposits into this stratigraphic framework. Furthermore, the authors speculated/concluded that:

1) quartz-feldspar meta-conglomerate in unit 4 marks an unconformity reflecting the uplift and erosion of Early Mississippian granitic rocks and their host rocks;
2) some of the mafic and ultramafic rocks in the area, considered by previous workers to be thrust slices, are intrusions, based on their three-dimensional form and lack of evidence for a basal thrust; and
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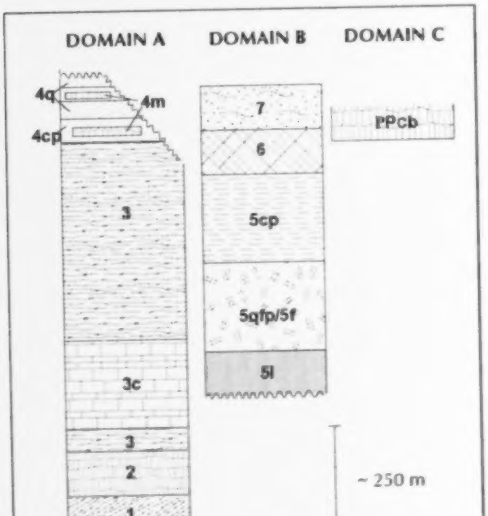

Figure 3. Stratigraphic columns from each of three domains discussed in text. Patterns as in Figure 2.

This report, in describing rocks immediately east of Grass Lakes map area, extends the area of stratigraphic and structural control from the Grass Lakes area and presents new conclusions on stratigraphically higher parts of Yukon-Tanana Terrane.

GEOLOGY OF NORTHERN WOLVERINE LAKE MAP AREA

The deformed and metamorphosed rocks of northern Wolverine Lake map area can be subdivided into three domains on structural and lithostratigraphic grounds (Fig. 2, 3). Domain A is underlain by the east-northeast striking succession of rocks mapped in Grass Lakes map area (units 1-4 and Early Mississippian orthogneiss of Murphy, 1997, 1998) which extends into Wolverine Lake map area. Domain B consists of a northwest-striking, northeast-dipping succession of rocks that truncates and overlies Domain A on the east, and lacks Early Mississippian orthogneiss. Domain C comprises the northwest-striking rocks of the Campbell Range belt which lie above the rocks of Domain B.

DOMAIN A

Domain A is largely underlain by felsic schist of unit 3 of Murphy (1997, 1998) with some exposure of units 1, 2, Mississippian orthogneiss, ultramafic rock, and Cretaceous granite (Fig. 3). Unit 1 occurs in two locations, between the western edge of the map area and the western contact of the nearby Cretaceous granite, and at the southern edge of the area mapped. It consists of tan- to brown-weathering muscovite-quartz[1] schist, locally with quartzofeldspathic grit(?) layers, quartz-muscovite-biotite schist, and lesser marble. Unit 2 also occurs in the same two areas where it comprises pale to medium green, weakly calcareous actinolite-plagioclase-biotite-chlorite schist.

Unit 3 is a heterogeneous unit made up of both meta-sedimentary and meta-volcanic rocks. Light grey weathering, grey and tan to brown biotite-muscovite-feldspar-quartz schist (Fig. 4a), commonly with mm- to cm-scale feldspar augen (Fig. 4b) is the dominant rock type. Locally, the matrix of these rocks is creamy white, fine-grained and siliceous. Biotite-rich quartz-feldspar-calcite-biotite schist ("biotitite," Fig. 4c) is commonly interfoliated with augen schist. Intervals of meta-sedimentary rock punctuate the dominantly felsic schist succession. These include calcareous quartz psammite and siliceous carbonaceous schist and quartzite, locally with soft, pale pink to rusty quartz-muscovite schist and magnetite-bearing semi-massive sulphide layers and lenses ("iron formation," Fig. 4d); and marble (Fig. 4e). The latter is locally thick enough to map as a separate unit 3c (Fig. 2, 3). Pale to medium green actinolite-quartz-plagioclase-biotite-chlorite schist similar to unit 2 also occurs locally in unit 3. Mortensen (1992)

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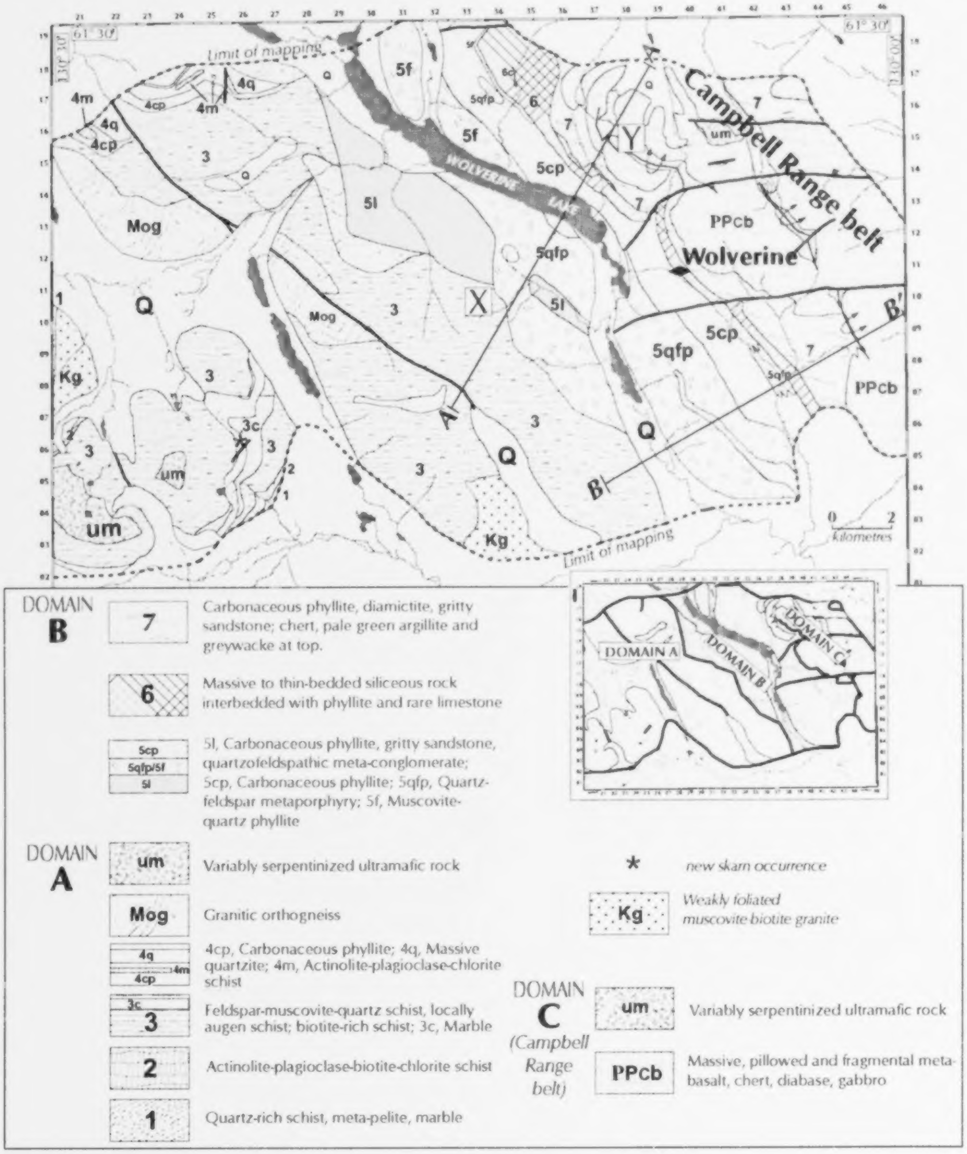
61° 30'
61° 30'
130° 30'
130° 00'
Limit of mapping
Limit of mapping
WOLVERINE LAKE
Campbell Range belt
Wolverine
X
Y
A
A'
B
B'
5f
5qfp
5cp
5l
5qfp
6
7
PPcb
Mog
Q
3
3c
4m
4q
4cp
um
Kg
1
2
0
2
Kilometres
DOMAIN A
DOMAIN B
DOMAIN C
DOMAIN B
7
Carbonaceous phyllite, diamictite, gritty sandstone; chert, pale green argillite and greywacke at top.
6
Massive to thin-bedded siliceous rock interbedded with phyllite and rare limestone
5cp
5qfp/5f
5l
5l, Carbonaceous phyllite, gritty sandstone, quartzofeldspathic meta-conglomerate; 5cp, Carbonaceous phyllite; 5qfp, Quartz-feldspar metaporphyry; 5f, Muscovite-quartz phyllite
DOMAIN A
um
Variably serpentinized ultramafic rock
Mog
Granitic orthogneiss
4q
4m
4cp
4cp, Carbonaceous phyllite; 4q, Massive quartzite; 4m, Actinolite-plagioclase-chlorite schist
3c
3
Feldspar-muscovite-quartz schist, locally augen schist; biotite-rich schist; 3c, Marble
2
Actinolite-plagioclase-biotite-chlorite schist
1
Quartz-rich schist, meta-pelite, marble
*
new skarn occurrence
Kg
Weakly foliated muscovite biotite granite
DOMAIN C (Campbell Range belt)
um
Variably serpentinized ultramafic rock
PPcb
Massive, pillowed and fragmental meta-basalt, chert, diabase, gabbro

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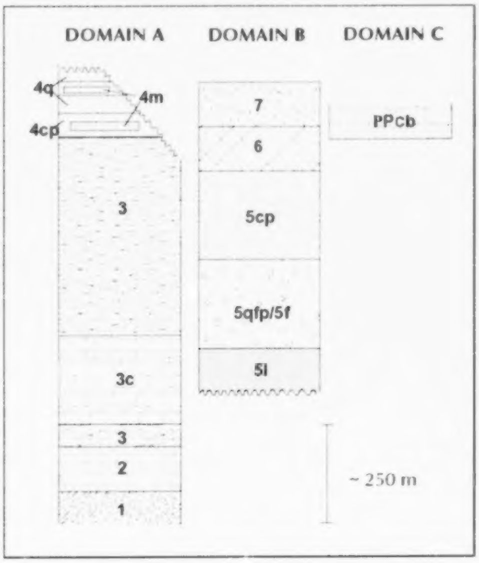

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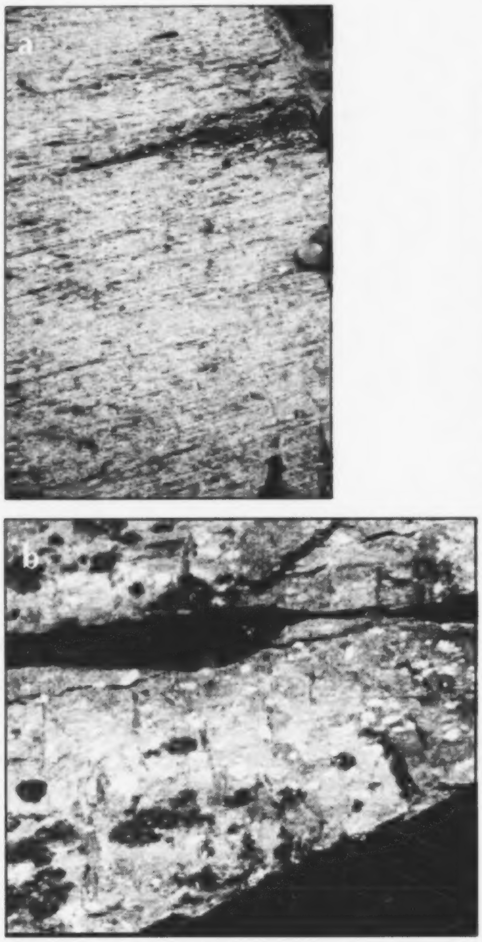

In the southwestern part of the area, beneath the ultramafic bodies capping the prominent peaks, the felsic and carbonaceous rocks are organized into thinning and fining upward cycles (Fig. 5). Each cycle is characterized by fine- to coarse-grained augen schist at the base and a meta-sedimentary top comprising siliceous carbonaceous schist, calcareous psammite and/or marble. In the uppermost cycles, the meta-sedimentary component predominates and consists mainly of siliceous carbonaceous phyllite, pale, locally rusty magnetite-bearing quartz-muscovite schist, and layers and lenses of magnetite-bearing semi-massive sulphide.

The fining and thinning upward cycles described above are overlain by a sheet of variably serpentinized ultramafic rock,

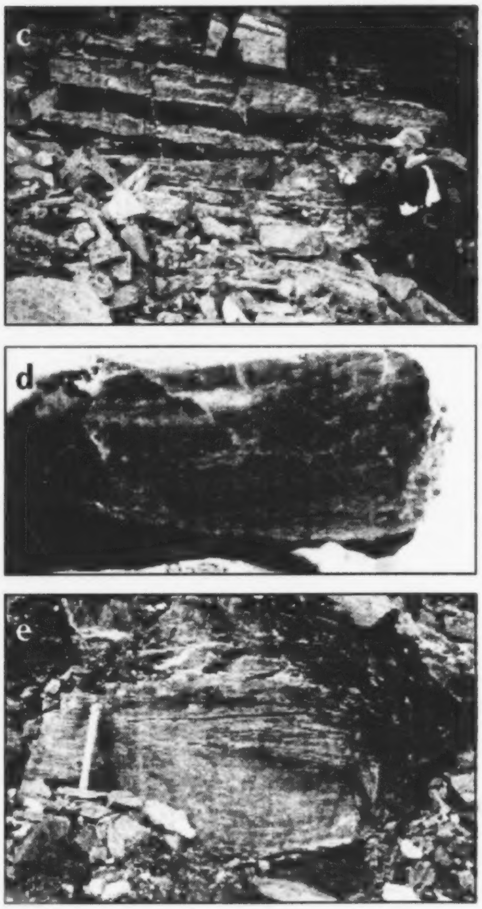

***Figure 4**. Unit 3: **a)** biotite-muscovite-feldspar-quartz schist with mm- to cm-scale feldspar augen; **b)** coarse feldspar augen biotite-muscovite-feldspar-quartz schist; **c)** biotite-rich quartz-feldspar-calcite-biotite schist ("biotitite;" dark layers) interlayered with felsic shist as in 4a; **d)** manganese zoisite-magnetite-pyrite ± sphalerite layer in carbonaceous schist near top of unit 3; **e)** unit 3c: coarse-grained grey marble and boudinaged calc-silicate layers.*

hence their stratigraphic position in unit 3 is unknown. However, a similar upward increase in siliceous carbonaceous phyllite occurs at the stratigraphic top of unit 3 in the northwestern part of the area. In this area, unit 3 feldspar augen muscovite-quartz schist is overlain by siliceous carbonaceous phyllite, with lesser pale quartz-muscovite schist, chlorite schist, greenstone, and massive quartzite of unit 4. Chlorite schist of unit 4 resembles unit 2 but is more massive (greenstone). The quartzite unit in the northwest corner of the map area is unique in the area in that it is massive to thick-bedded, ranges in colour from mottled grey/white, to pink and purple and occurs in a mappable thickness (greater than 300 m thick in cross section). This quartzite unit has been traced for over 5 km, defining the east-northeast strike of the strata. It disappears into the Wolverine Lake valley and doesn't re-appear along strike to the east.

Bodies of coarse-grained equigranular granitic orthogneiss occur throughout Domain A (Fig. 6). These are similar to Grass Lakes orthogneiss in Grass Lakes map area to the west. They also resemble feldspar-augen meta-volcanic schist that occurs in the same area in unit 3. These two meta-igneous rock types are distinguished by the grain size of the matrix: if the quartz-rich matrix is coarse-grained and massive, then the rock is inferred to be meta-plutonic (unit Mog); if fine-grained and schistose, then the rock is inferred to be either a porphyritic meta-volcanic or a high-level, meta-plutonic rock. The intrusive nature of these bodies is attested to by the local occurrence of skarn near contacts with calcareous host rocks and the increase in number of metre-scale bodies of granitic orthogneiss toward the contact with the larger bodies.

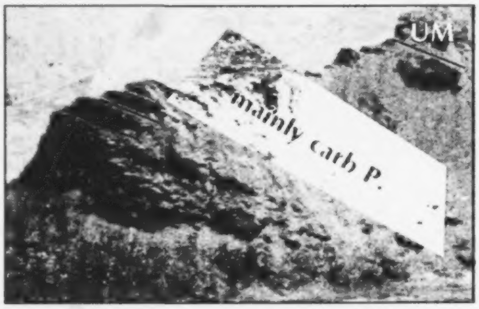

Figure 5. *Thinning and fining upward cycles at top of unit 3.*

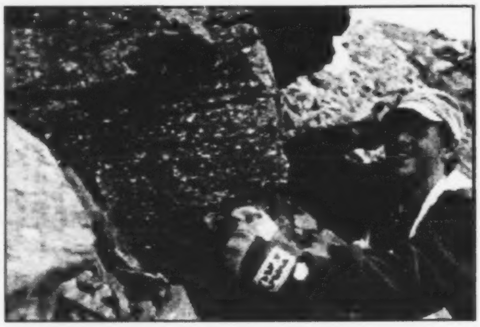

Figure 6. *Coarse-grained equigranular granitic orthogneiss in central part of area.*

Dun- to chocolate brown-weathered, dark green to black, variably serpentinized ultramafic rocks, previously considered to be part of Anvil Allochthon or Slide Mountain Terrane (North Klippen of Tempelman-Kluit, 1979), cap the two prominent peaks in the western part of the map area (Fig. 2). Ultramafic rock is typically massive, unfoliated and cut by serpentine-filled fractures/veins. Fish-scale serpentinite is rarely observed and likely indicates small-displacement fault zones. Relic coarse-grained (cm-scale and larger) crystals of a blocky mineral phase, probably orthopyroxene, occur locally. Magnetite is a common constituent of these rocks; they have strong magnetic signatures on aeromagnetic maps (DMTS, 1961; GSC, 1998). In the westernmost of the two peaks, the contact with underlying rocks of unit 3 is sharp and well exposed in several places (Fig. 7). At these exposures, unit 3 is very hard and finely but strongly foliated and lineated, fine-grained felsic schist with a distinct maroon cast. Ultramafic rock above the contact is fractured but not more than elsewhere. Even with good exposure, it is not clear if the contact is a fault or a deformed intrusive contact.

The mapped area includes part of two weakly foliated granite plutons, both in Domain A. The eastern side of a northwardly-elongate batholith occurs in the western part of the map area.

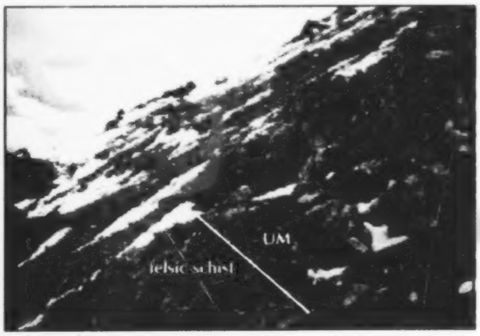

Figure 7. *Contact between ultramafic rocks capping peak in western part of map area and hard, fine-grained muscovite-quartz schist of unit 3.*

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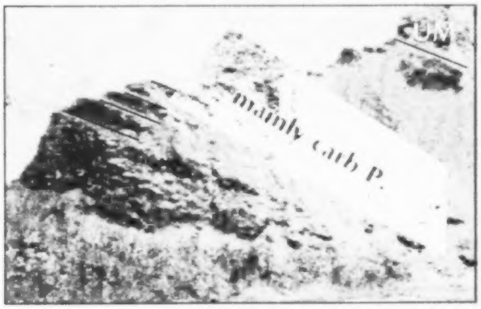

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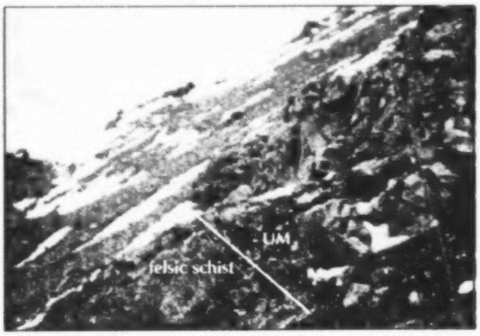

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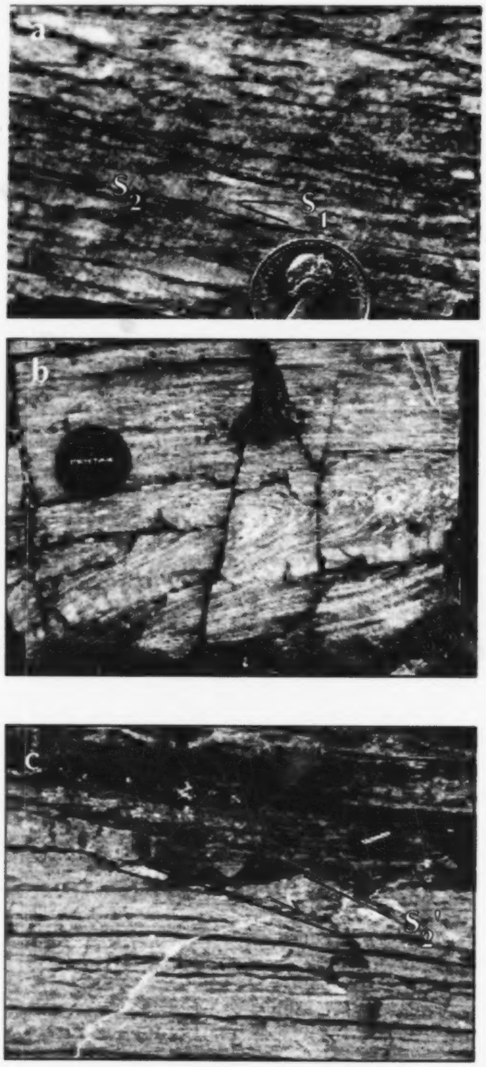

Figure 8. a) *Doubly foliated rocks of Domain A;* ***b)*** *folded foliations;* ***c)*** *view to east of outcrop face parallel to lineation and perpendicular to foliation showing shear bands with top-to-south vergence.*

The second is an incompletely mapped granite pluton in the southern part of the map area. Both bodies are weakly foliated, medium- to coarse-grained, tourmaline-bearing muscovite-biotite granite. Although weakly foliated, they truncate the main foliation in the country rocks, and dykes emanating from the larger bodies are folded; both observations suggest late synkinematic intrusion with respect to the prominent foliation in the country rock. Country rock adjacent to the contact is recrystallized. Mid-Cretaceous U-Pb ages have been determined for both of these bodies (110-113 Ma, J. Mortensen, pers. comm., 1996).

Rocks of Domain A host two kinds of mineral occurrences, volcanic-hosted massive sulphide mineralization and skarn. The Kudz Ze Kayah volcanic-hosted massive sulphide deposit (Yukon Minfile 105G 117) and other occurrences of this type of mineralization (Pack, 105G 032; Cobb, Overtime claims) occupy a stratigraphic position near the top of unit 3 in Grass Lakes map area. The same stratigraphic interval in Wolverine Lake map area is marked by felsic schist and carbonaceous phyllite which locally includes black-weathered, pyrolusite-coated, foliated green manganese zoisite-magnetite-pyrite ± sphalerite ± galena-bearing rock (Goal Net I target of Expatriate Resources). In eastern Grass Lakes map area, skarn showings occur on Expatriate Resources' Goon claims where marble is in contact with Early Mississippian orthogneiss, and at the Myda occurrence (#105G 071) where the same marble is in contact with a Cretaceous granite. In Wolverine Lake map area, we located a previously unreported skarn showing at the contact between an Early Mississippian sill and unit 3c (Fig. 2).

The layered metamorphic rocks and most bodies of Early Mississippian orthogneiss of Domain A show evidence for two profound phases of penetrative deformation followed by later upright, open folding and high-angle faulting. In any given outcrop, two foliations are typically visible. The first, S1, is typically inclined in microlithon domains between the prominent folia of the other, (S2; Fig. 8a). Tight to isoclinal, generally south- or southwest-vergent folds occur locally; these typically fold S1 and have S2 for an axial-planar fabric (Fig. 8b). S2 is deflected sigmoidally by S2′ shear bands with top to the south displacement, parallel to a prominent quartz-rodding and mineral-streaking lineation, (L2; Fig. 8c). Shear bands both deflect and are asymptotic to S2, implying that they formed during the same deformation (D2).

Late folds and faults are indicated by systematic changes in orientation of S2 (Fig. 9). In area 1 of Fig. 9, changes in orientation of S2 define a structural basin beneath the western ultramafic body. Across Domain A in an east-west direction, S2 changes from northeast-striking, northwest-dipping to northwest-striking and northeast-dipping around north-northwest-striking axial surfaces (areas 2 and 3, Fig. 9). The transitions locally coincide with high-angle north-northwest-striking faults.

In spite of the late folding of S2, the structural and stratigraphic grain of Domain A is broadly east-northeast striking. Within a kilometre of Domain B, the structural grain changes to northwestwardly striking, sub-parallel to that of Domain B. The stratigraphic grain, however, must still be inclined to that of Domain B because the westernmost unit of Domain B is next to different units of Domain A in different parts of the map area (Fig. 2).

DOMAIN B

The east-northeast striking stratigraphic succession of Domain A is truncated to the east by the northwest-striking, northeast-dipping strata of Domain B (Fig. 2). For reasons outlined in a separate upcoming section, the contact between the Domain A and B is interpreted as an angular unconformity for part of its extent and as an intrusive contact for the remainder.

The lowest stratigraphic unit of Domain B is unit 5, which consists of a lower member of carbonaceous phyllite and grey gritty quartzofeldspathic meta-sandstone with variable amounts of quartzofeldspathic meta-conglomerate (unit 5l, Fig. 10a), and an upper member comprising laterally and vertically variable amounts of quartz-feldspar meta-porphyry (5qfp, Fig. 10b); muscovite-quartz phyllite (5f); grey, locally gritty, sandstone with glassy black quartz and argillite clasts; and carbonaceous phyllite (5cp, Fig. 10c). Unit 5l is typically overlain by quartz-feldspar meta-porphyry except south-southwest of Wolverine Lake (location X on Fig. 2). Here, quartz-feldspar meta-porphyry both overlies and underlies unit 5l, and is in direct contact with felsic schist of unit 3. This relationship is further discussed in the section on contacts between the domains.

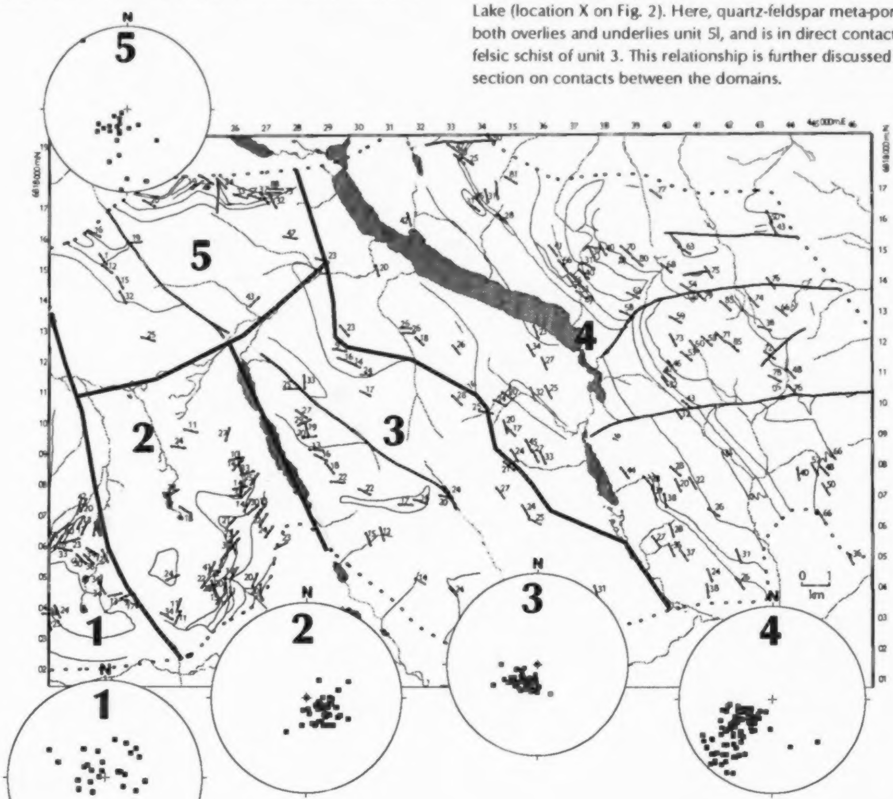

Figure 9. Structural measurements and stereoplots of S2 illustrating its change in orientation across the map area.

Conformably overlying unit 5 is a thin but laterally persistent unit consisting primarily of cream to tan siliceous rock and barite-magnetite iron formation interbedded with lesser amounts of muscovite-quartz phyllite and carbonaceous phyllite (unit 6). At the base of unit 6, the siliceous rock is massive to thick-bedded, locally characterized by boxwork pyrite and interbedded with tan muscovite-quartz phyllite (Fig. 11a). Upsection, bed thickness decreases to cm- and mm-scale and interbedded phyllite becomes grey (Fig. 11b, c). A metre-scale brown marble band occurs in the upper part of the unit.

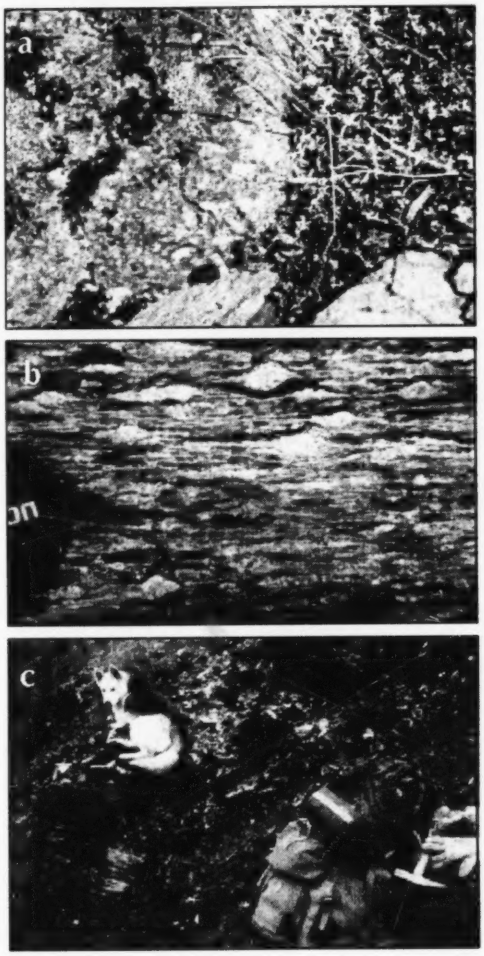

Figure 10. a) *Unit 5l: quartzofeldspathic meta-conglomerate;* ***b)*** *Unit 5qfp: quartz-feldspar meta-porphyry. Note shear bands. View is to the east and surface is parallel to lineation so hanging wall transport is to the south;* ***c)*** *Unit 5cp: carbonaceous phyllite and grey quartz meta-sandstone.*

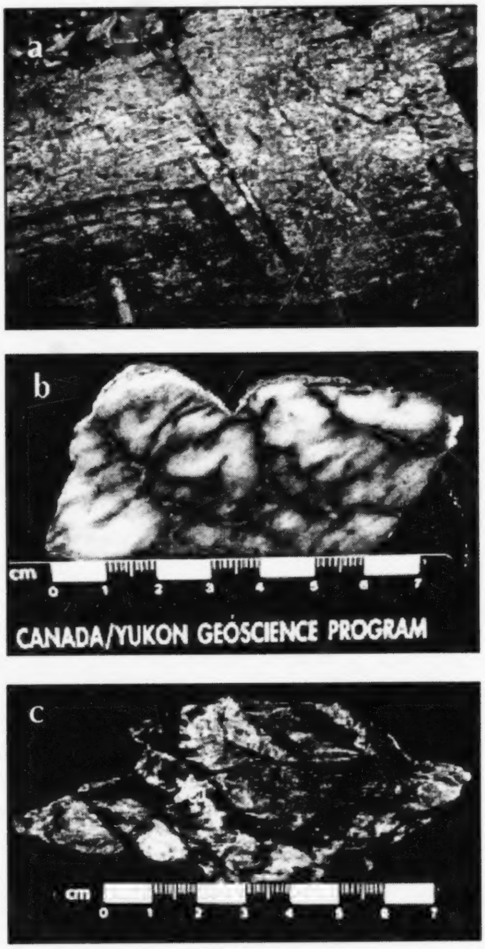

Figure 11. *Unit 6:* ***a)*** *cream to tan siliceous rock with barite-magnetite iron formation;* ***b)*** *cm-scale beds of siliceous rock with lesser mm-scale beds of muscovite-quartz phyllite;* ***c)*** *cm-scale beds of siliceous rock with subequal amounts of cm-scale beds of carbonaceous phyllite*

Unit 7 comprises carbonaceous phyllite and grey, locally gritty meta-sandstone with lesser amounts of chloritic phyllite and diamictite. The diamictite is a matrix-supported conglomerate made up of isolated centimetre- to decimetre-scale clasts of felsic and mafic meta-volcanic rock and quartz-pebble meta-conglomerate in a matrix of carbonaceous phyllite (Fig. 12a). Grey ribbon chert (Fig. 12b), greywacke with shale chips, coarse-grained limestone, and pale green, fine-grained siliceous argillite occur toward the top (Fig. 12c). These latter rock types are interbedded in rare outcrops with breccias made up of basalt clasts.

Rocks of Domain B host volcanic-hosted massive sulphide mineralization. The Wolverine massive sulphide deposit (Yukon Minfile 105G 072) and nearby mineralized zones (Fisher, Lynx, Sable) occur near the contact between units 5 and 6 (Fig. 2). The spatial association of unit 6 with this belt of volcanic-hosted massive sulphide mineralization and its association with barite-magnetite iron formation suggests that the siliceous layers of unit 6 are of exhalite origin.

In comparison to those of Domain A, rocks of Domain B are less deformed and bedding and other primary structures are more readily recognized. Like Domain A, Domain B rocks are foliated, lineated, folded by southwest-vergent folds and locally deformed by late kink folds and crenulations of the foliation. The prominent foliation affecting Domain B (S1) is a curviplanar pressure-solution foliation that is defined by finely spaced seams of concentrated micas and insoluble residue in phyllite layers, and more coarsely spaced seams of mica/insoluble residue in more siliceous layers (see Fig. 11b, c). The foliation is axial-planar to outcrop- and larger-scale, open to tight, upright to southwest-overturned folds that have a first-order southwest-vergence. The axial-planar relationship is especially evident at the higher stratigraphic and structural level of unit 6 and 7 where foliation and bedding are typically at a relatively large angle (Fig. 12b) and their intersection produces an intersection lineation that parallels the hinges of these folds. At the stratigraphic level of unit 5, bedding/compositional layering and foliation are sub-parallel and folds are tight to isoclinal, both of which suggest a downward increase in strain. Foliation surfaces at this level are characterized by a quartz-rodding lineation that trends southerly; shear bands in quartz-feldspar meta-porphyry at this level suggest hanging wall transport to the south, parallel to the lineation (Fig. 10b). At the stratigraphic level of unit 5, the character of the structural fabric resembles that of the second phase of deformation in Domain A, with one important difference. Although Domain B rocks have not yet been examined in thin section, the pressure-solution foliation looks to be the first foliation in the rock and does not appear to be a crenulation of an earlier fabric as observed in Domain A.

DOMAIN C (CAMPBELL RANGE BELT)

Lying above unit 7 of Domain B is a folded yet gently dipping sheet of meta-basalt, argillite, chert, diabase, gabbro and serpentinized ultramafic rock of Domain C (Campbell Range

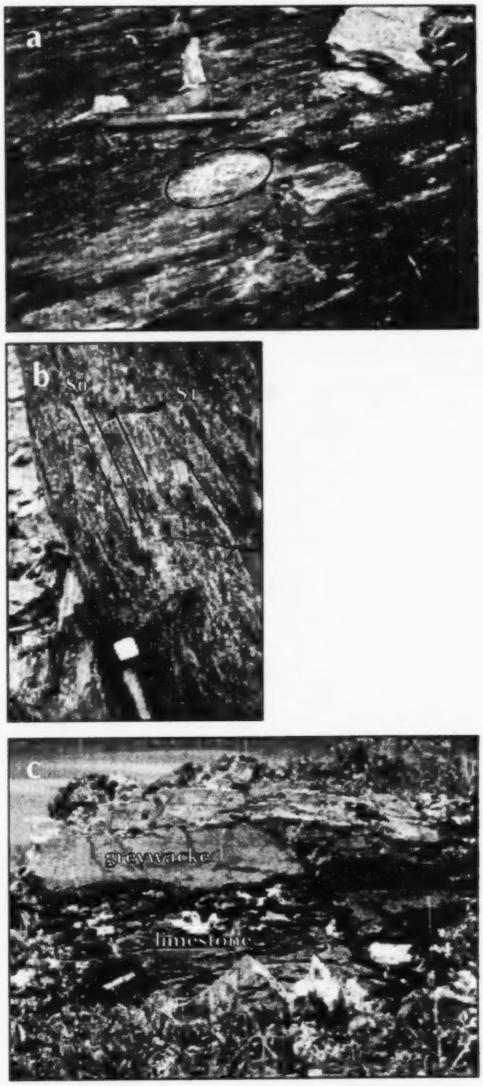

Figure 12. *Unit 7:* ***a)*** *diamictite, clast of quartz-pebble meta conglomerate outlined;* ***b)*** *beds of chert in silicous argillite (bedding, So, indicated). View is to the southeast and cleavage-bedding relationship indicates that outcrop is on the southwestern limb of anticline;* ***c)*** *limestone and greywacke.*

belt of Mortensen and Jilson, 1985; Mortensen, 1992; Plint and Gordon, 1997; units PPCb and um of Fig. 2). As will be discussed in an upcoming section, the contact between Domains B and C is inferred to be depositional.

Massive meta-basalt is the dominant rock type with pillowed and fragmental varieties occurring locally (Figs. 13a, b). Massive basalt is generally dark green to black, variably foliated and locally marked by magnetite-bearing reddish jasperoidal silica and pale green epidote-quartz veins. Decimetre- to metre-scale pillows are locally well preserved and indicate that with the exception of short overturned limbs of southwest-vergent folds, the sequence is generally upright. Fragmental meta-basalt is light reddish brown and variably foliated and lineated. These fine- to coarse-grained monomictic breccias consist of angular basalt fragments and carbonate or chlorite cement. Polymictic breccias elsewhere in the Campbell Range were described by Plint and Gordon (1997).

Less common rock types in the Campbell Range include maroon or green silty and siliceous argillite, chert, and mafic and ultramafic meta-plutonic rocks. Plint and Gordon (1997) described interbeds of radiolarian chert in meta-basalt from which they obtained a mid-Pennsylvanian to Early Permian age (identification by T. Harms). Mafic meta-plutonic rocks with fine- to medium-grained diabasic texture occur throughout the Campbell Range belt; although no contacts were observed, Plint and Gordon (1997) reported intrusive relationships. Aeromagnetically prominent bodies of serpentinized ultramafic rock occur in the northeastern part of the area. The contacts aren't exposed although scaly foliated serpentinite occurs near the southern margin of one body implying a locally faulted contact (Fig. 14).

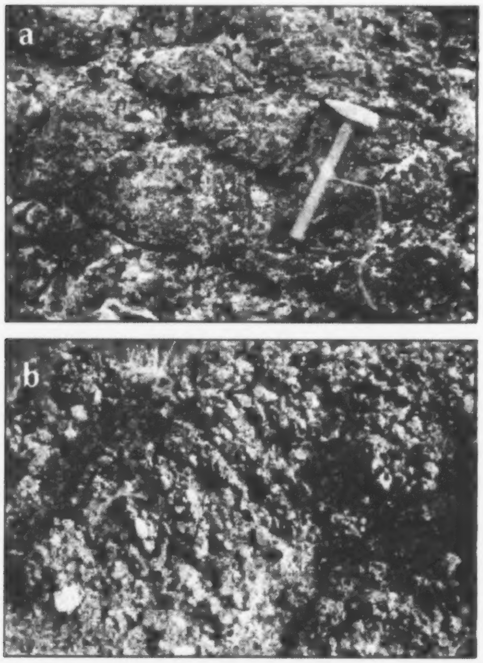

***Figure 13**. Campbell Range meta-basalt: **a)** pillowed, **b)** fragmental.*

No mineral occurrences are known in Domain C in northern Wolverine Lake map area. Magnetite-bearing jasperoidal silica occurs locally and rusty, pyritic zones occur along late east-striking normal faults. Campbell Range meta-basalt hosts the Money occurrence just outside the map area to the east, and Expatriate Resources' Ice deposit occurs about 90 km along strike to the northwest in basaltic rocks possibly correlative to the Campbell Range basalt (Hunt, 1998a).

Domain C has a similar structural style to Domain B. Fragmental and pillowed meta-basalt are foliated and lineated with fragmental rocks showing a stronger degree of fabric development. Foliation and lineation are axial-planar to open to tight, upright to southwest-overturned, southwest-vergent folds that occur in both Domain B and C, and fold the contact between the two domains (Fig. 15). A synclinal keel of meta-basalt at the western edge of the belt is more strongly foliated than the eastern part of the belt (Figs. 2, 15, location Y), probably owing to the tightness of the folding (see Discussion). Steep, east-striking normal faults cut both Domain B and C.

NATURE OF CONTACTS BETWEEN THE DOMAINS

Figure 16 summarizes our interpretation of the contacts between the domains. The contact between Domains A and B is inferred to be an angular unconformity where between unit 5l

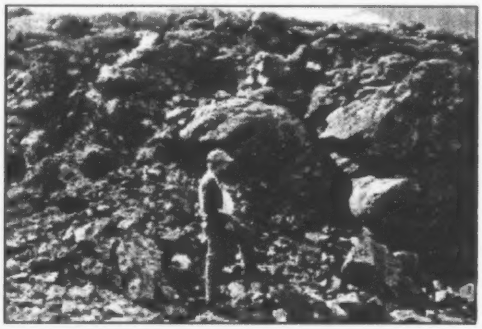

***Figure 14**. Scaly foliated serpentinite near contact of ultramafic rocks and massive meta-basalt in Campbell Range belt.*

and underlying rocks, and a deformed intrusive contact where between unit 5qfp and unit 3. The contact between Domains B and C is interpreted as a conformable depositional contact.

Three lines of evidence support the interpretation of an angular unconformity beneath unit 5l. First of all, unit 5l, the lowest unit of Domain B, comprises quartzofeldspathic meta-conglomerate in its lower part. Locally, feldspar clasts in the conglomerates are cm-sized and angular, and detrital zircons are euhedral (J. Mortensen, pers. comm., 1998), implying a local source. The coarse-grained meta-plutonic rocks of Domain A are obvious candidates for a local source. If so, then Domain A must have been uplifted and eroded to the extent that meta-plutonic rocks within it were exposed before the deposition of unit 5l. Secondly, rocks of Domain A are more highly deformed than Domain B and possibly have undergone an additional phase of deformation. Where the contact can be constrained to within a few metres, the change is abrupt, yet no structural features there indicate a fault or shear zone boundary. If depositional, then the underlying rocks must have been intruded, deformed, intruded again, uplifted and eroded before the deposition of unit 5l. This sequence is supported by preliminary geochronological data on two weakly foliated yet discordant intrusions in Domain A, originally thought to be Cretaceous, which yielded Early Mississippian ages (J. Mortensen, pers. comm., 1998). Thirdly, an angular discordance between Domain A and Domain B is required by two observations: 1) unit 5l rests upon different units of Domain A, and 2) there is a general discordance in strike between the domains such that strata of Domain A strike into the basal unit of Domain B.

The interpretation that the contact between unit 3 and unit 5qfp is a deformed intrusive contact is based on geological relationships south-southwest of Wolverine Lake (location X on Fig. 2). Here, quartz-feldspar meta-porphyry both overlies and underlies unit 5l, and quartz-feldspar meta-porphyry, with a single foliation, is in direct contact with polydeformed felsic schist of unit 3. A reasonable explanation for this relationship is that where unit 5qfp lies beneath unit 5l, it is a subvolcanic feeder to the meta-porphyries that overlie unit 5l, and the contact between unit 3 and unit 5qfp is intrusive. In this interpretation, where unit 5qfp underlies unit 5l, the contact between the two would also have to be intrusive.

The contact between Domains B and C is inferred to be depositional. First of all, the top of unit 7 includes pale green siliceous phyllite and meta-sandstone as well as some of the rock types of the Campbell Range belt such as thin-bedded chert and rare fragmental meta-basalt with carbonate cement. The occurrence of these rock types at the top of unit 7 suggests a transitional contact with Campbell Range meta-basalt. Secondly, the contact exhibits no structural evidence of a fault or shear zone. The base of the sheet of Campbell Range meta-basalt has been observed with relatively good exposure both along strike and across strike in anticlinal hinge zones (Figs. 2, 15). Everywhere along this contact, the meta-basalt sits above the transitional-looking upper part of unit 7, and there are no increases in the amount of fracturing or strength of foliation, slickensides or gouge. Meta-basalt and unit 7 are folded conformably around first-order upright to southwestwardly overturned, southwest-vergent folds with a gently dipping enveloping surface (Fig. 15).

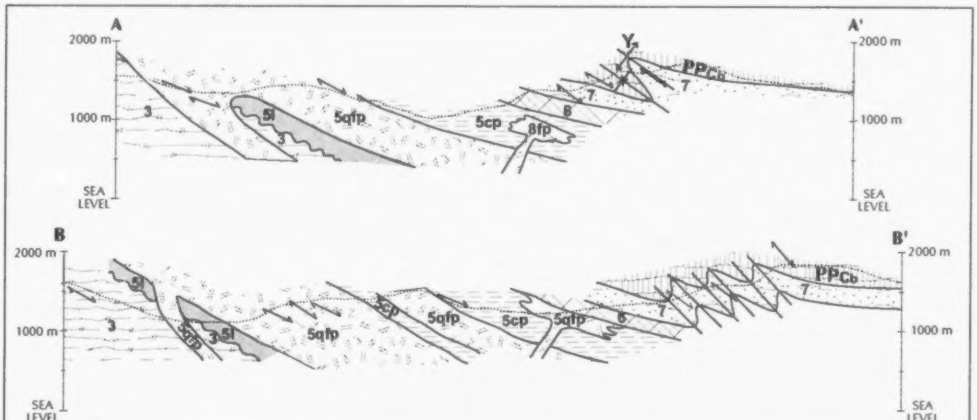

Figure 15. Cross sections of northern Wolverine Lake map area. Location and legend are as in Fig. 2. The unconformable contact between units 3 and 5l, the intrusive contact between units 3 and 5qfp, and the contact between unit 7 and PPCb (Campbell Range belt) are discussed in the text.

DISCUSSION

We have presented evidence for a previously unrecognized angular unconformity in Yukon-Tanana Terrane, an unconformity that marks the completion of an episode of deformation, metamorphism, plutonism and uplift. The unconformity is broadly Early Mississippian in age, based on relatively imprecise Early Mississippian U-Pb ages of late-kinematic meta-plutonic rocks below the unconformity and quartz-feldspar meta-porphyry above the unconformity (J. Mortensen, pers. comm., 1998). The unconformity's short time gap indicated by the geochronological data and the apparently rapid restoration of continental magmatic arc activity after the unconformity imply that it may only be a local intra-arc feature. However, nearby Stewart Lake and Simpson Range eclogites also have Early Mississippian mica cooling ages (Erdmer et al., 1998), permitting the possibility of a linkage between the tectonic activity indicated by the unconformity, and the formation and exhumation of the eclogites. If it is of regional extent and significance, this unconformity may be a useful feature in correlating between widely separated areas of Yukon-Tanana Terrane. Further work is needed to determine the regional extent of Early Mississippian tectonism and its significance.

Secondly, our new work shows that the strata hosting the Wolverine and Kudz Ze Kayah massive sulphide deposits are different. The Wolverine deposit occurs in Domain B above the unconformity and Kudz Ze Kayah, below, in Domain A. This distinction explains the differences in stratigraphic, structural, metamorphic and geochemical character that have been noted by geologists who have visited both deposits. It also adds another stratigraphic horizon to the growing list of horizons known to host VMS deposits in Yukon-Tanana Terrane.

Thirdly, our location of the contact between unit 7 and meta-basalt of the Campbell Range belt, and our interpretation of it as depositional, differ from previous interpretations. Tempelman-Kluit (1977, 1979) located the contact of Anvil Allochthon (Wolverine Klippen=Campbell Range belt) at approximately the same place as our study but interpreted it as a thrust fault. He shows the Anvil Allochthon as a gently dipping sheet capping topographically high areas, with low-lying rocks belonging to the underlying Yukon-Tanana Terrane. Mortensen and Jilson (1985) located the basal contact of rocks of the Campbell Range belt northeast of where we placed it and interpreted it as a synformally folded thrust fault. Furthermore, they interpreted topographically low outcrops of meta-chert, argillite, lesser felsic and mafic meta-volcanic rocks, and serpentinite surrounded by the main body of Campbell Range meta-basalt as a klippe lying above the meta-basalt. Similarly, Plint and Gordon (1997) located the basal contact of rocks of the Campbell Range belt northeast of where we located it, but not as far to the northeast as Mortensen and Jilson (1985), and interpreted the low-lying meta-chert and argillite unit as a structurally overlying klippe.

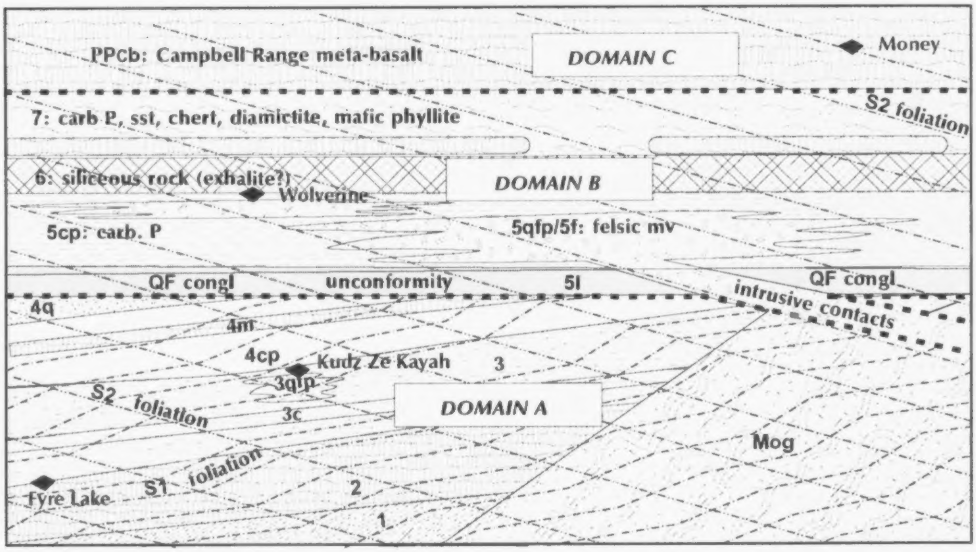

Figure 16. Schematic cross section summarizing structural and stratigraphic relationships between the domains. See text for discussion.

DISCUSSION

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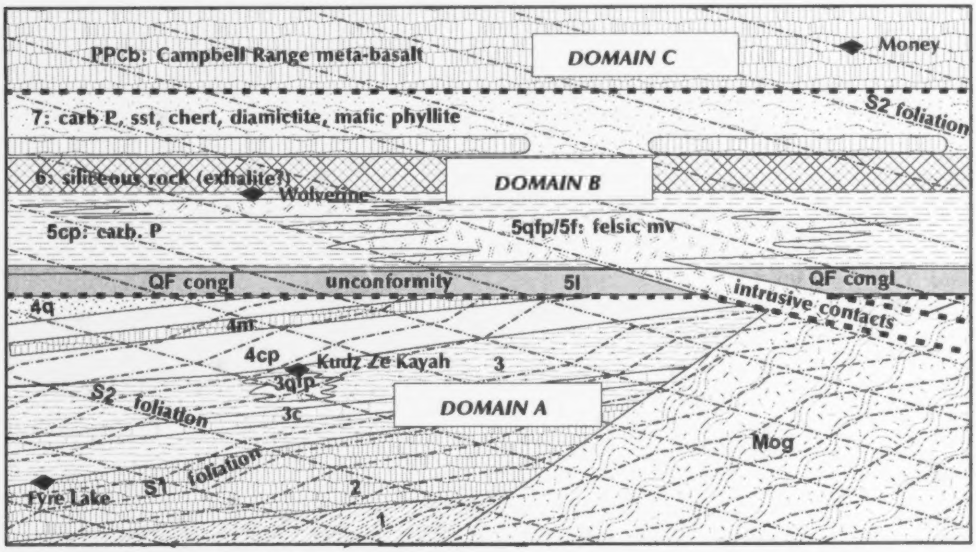

Figure 16. Schematic cross section summarizing structural and stratigraphic relationships between the domains. See text for discussion.

Instead of a single synformally folded thrust, however, they proposed that the southwestern boundary of the belt was a southwest-vergent thrust fault and the northeastern boundary was an older northeast-vergent thrust fault.

In examining where previous workers located the faulted base of Campbell Range belt/Anvil Allochthon, we observe similar rocks on both sides, differing only in the state of strain. For example, Plint and Gordon (1997) map the faulted base of the Campbell Range belt through locality Y in Fig. 2. Northeast of their fault trace are typical weakly strained massive and fragmental meta-basalt of the Campbell Range belt and conformably underlying pale green siliceous argillite and meta-chert, carbonaceous phyllite and grey gritty greywacke with argillite chips. However, southwest of the trace, strongly foliated, pillowed and fragmental meta-basalt that is geochemically identical to Campbell Range meta-basalt (Plint and Gordon, 1997; Piercey et al., this volume) occurs in a synclinal keel enclosed by carbonaceous phyllite, meta-chert, green siliceous argillite and gritty meta-sandstone of unit 7. The syncline is defined by changes in orientation of the basal contact of the meta-basalt and changes in vergence of minor structures (second- and third-order folds, and cleavage-bedding relationships). Our structural and stratigraphic observations at this locality are more consistent with the interpretation that the conformable base of the meta-basalt is deformed into a tight, northwest-trending, southwest-overturned, southwest-vergent anticline-syncline pair, rather than being faulted (section A-A', Fig. 15).

We agree with Tempelman-Kluit's (1977) interpretation that the topographically low rocks that Mortensen and Jilson (1985) and Plint and Gordon (1997) included in klippe above the Campbell Range meta-basalt actually physically underlie the meta-basalt. The contact between the Campbell Range meta-basalt and unit 7 is folded around upright to overturned, northwest-trending, southwest-vergent folds. Isolated exposures of unit 7 occur at about the same elevation along axial-surface traces of adjacent first-order anticlines, suggesting that the enveloping surface of these folds dips subhorizontally in the map area. With such an orientation, the basal contact of the meta-basalt would project to the north above the low-lying rocks. Although these rocks have not yet been examined, their description resembles that of units 5, 6 and 7 which is what would be expected to underlie the meta-basalt. Hence, our working hypothesis is that the low-lying rocks are units 5, 6, and 7 occurring in a topographic window through the meta-basalt.

If our interpretation that the Campbell Range meta-basalt depositionally overlies Yukon-Tanana Terrane is correct, then this contact marks a profound shift in the tectonic evolution of the Yukon-Tanana crustal block. Rocks of Yukon-Tanana Terrane below this contact represent a mid-Paleozoic continental magmatic arc (Mortensen and Jilson, 1985; Mortensen, 1992). Rocks above this contact formed in an oceanic or marginal basin setting. This transition which occurred sometime in the Pennsylvanian or Permian can be explained in many ways, none of which can be reasonably constrained with current information. This and other questions will be addressed by future research.

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REFERENCES

DMTS, 1961. Finlayson Lake (105G), Airborne Magnetic Map. Department of Mines and Technical Surveys, Geophysical Paper 70006G.

Erdmer, P., Ghent, E.D., Archibald, D.A. and Stout, M.Z.,1998. Paleozoic and Mesozoic high-pressure metamorphism at the margin of ancestral North America in central Yukon. Geological Society of America Bulletin, vol. 110, p. 615-629.

GSC, 1998. Airborne Geophysical Survey, Grass Lakes area (NTS 105G/2, 7, 8). Geological Survey of Canada, Open File 3552.

Hunt, J.A., 1997. Massive sulphide deposits in the Yukon-Tanana Terrane and adjacent terranes. *In:* Yukon Exploration and Geology 1996, Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 35-45.

Hunt, J.A., 1998a. The setting of volcanogenic massive sulphide deposits in the Finlayson Lake district. *In:* Yukon Exploration and Geology 1997, Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 99-104.

Hunt, J.A., 1998b. Recent discoveries of volcanic-associated massive sulphide deposits in the Yukon. Canadian Institute of Mining and Metallurgy, Bulletin, vol. 90, p. 56-65.

Hunt, J.A. and Murphy, D.C., 1998. A note on preliminary bedrock mapping in the Fire Lake area. *In:* Yukon Exploration and Geology 1997. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 59-68.

Mortensen, J.K., 1983. Age and evolution of the Yukon-Tanana Terrane, southeastern Yukon Territory. Unpublished Ph.D thesis, University of California, Santa Barbara, 155 p.

Mortensen, J.K., 1990. Geology and U-Pb geochronology of the Klondike District, west-central Yukon Territory. Canadian Journal of Earth Sciences, vol. 27, p. 903-914.

Mortensen, J.K., 1992. Pre-mid-Mesozoic tectonic evolution of the Yukon-Tanana Terrane, Yukon and Alaska. Tectonics, vol. 11, p. 836-853.

Mortensen, J.K. and Jilson, G.A., 1985. Evolution of the Yukon-Tanana Terrane: Evidence from southeastern Yukon Territory. Geology, vol. 13, p. 806-810.

Murphy, D.C., 1997. Preliminary geological map of Grass Lakes area, Pelly Mountains, southeastern Yukon (105G/7). Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, Open File 1997-3, 1:50 000 scale.

Murphy, D.C., 1998. Stratigraphic framework for syngenetic mineral occurrences, Yukon-Tanana Terrane south of Finlayson Lake: A progress report. *In:* Yukon Exploration and Geology 1997, Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 51-58.

Murphy, D.C. and Piercey, S.J., 1998. Preliminary geological map of northern Wolverine Lake area (NTS 105G/8, north half). Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, Open File 1998-4.

Murphy, D.C. and Timmerman, J.R.M., 1997a. Preliminary geological map of part of Grass Lakes area, Pelly Mountains, southeastern Yukon (105G/7). Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, Open File 1997-1, 1:50 000 scale.

Murphy, D.C. and Timmerman, J.R.M., 1997b. Preliminary geology of the northeast third of Grass Lakes map area (105G/7), Pelly Mountains, southeastern Yukon. *In:* Yukon Exploration and Geology 1996, Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 62-73.

Piercey, S.J., Hunt, J.A. and Murphy, D.C., 1999 (this volume). Lithogeochemistry of meta-volcanic rocks from Yukon-Tanana Terrane, Finlayson Lake region, Yukon: preliminary results. *In:* Yukon Exploration and Geology 1998, C.F. Roots and D.S. Emond (eds.), Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 125-138.

Plint, H.E., 1995. Geological mapping in the Campbell Range, southeastern Yukon (parts of 105G/8/9 and 105H/12). *In:* Yukon Exploration and Geology 1994. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 47-57.

Plint, H.E. and Gordon, T.M., 1995. The Slide Mountain Terrane and Finlayson Lake fault zone: marginal basin rocks in a transpressive setting? Evidence from the Campbell Range, southeastern Yukon. *In:* Lithoprobe Slave - Northern Cordillera Lithospheric Evolution, F. Cook and P. Erdmer (eds.), Report No. 44, p. 33-50.

Plint, H.E. and Gordon, T.M., 1996. Structural evolution and rock types of the Slide Mountain and Yukon-Tanana terranes in the Campbell Range, southeastern Yukon Territory. *In:* Current Research, Part A. Geological Survey of Canada, Paper 96-1A, p. 19-28.

Plint, H.E. and Gordon, T.M.,1997. The Slide Mountain Terrane and the structural evolution of the Finlayson Lake fault zone, southeastern Yukon. Canadian Journal of Earth Sciences, vol. 34, p. 105-126.

Schultze, H.C., 1996. Summary of the Kudz Ze Kayah project, volcanic-hosted massive sulphide deposit, Yukon Territory. *In:* Yukon Exploration and Geology 1995, Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 29-32.

Tempelman-Kluit, D.J., 1977. Quiet Lake (105F) and Finlayson Lake (105G) map areas, Yukon Territory. Geological Survey of Canada, Open File 486.

Tempelman-Kluit, D.J., 1979. Transported cataclasite, ophiolite and granodiorite in Yukon Territory: evidence of arc-continent collision. Geological Survey of Canada, Paper 79-14.

Tucker, T.L., Turner, A.J., Terry, D.A. and Bradshaw, G.D., 1997. Wolverine massive sulphide project, Yukon. *In:* Yukon Exploration and Geology 1996, Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 53-55.

Wheeler, J.O. and McFeely, P., 1991. Tectonic assemblage map of the Canadian Cordillera and adjacent parts of the United States of America. Geological Survey of Canada, Map 1712A, 1:2 000 000 scale.

Wheeler, J.O., Green, L.H. and Roddick, J.A., 1960. Finlayson Lake map area, Yukon Territory. Geological Survey of Canada, Map 8-1960.

Yukon Minfile. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada. Also available from Hyperborean Productions, Whitehorse, Yukon.

Glenlyon project: Preliminary stratigraphy and structure of Yukon-Tanana Terrane, Little Kalzas Lake area, central Yukon (105L/13)

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Yukon Geology Program

Colpron, M., 1999. Glenlyon project: Preliminary stratigraphy and structure of Yukon-Tanana Terrane, Little Kalzas Lake area, central Yukon (105L/13). *In:* Yukon Exploration and Geology 1998, C.F. Roots and D.S. Emond (eds.), Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 63-71.

ABSTRACT

Yukon-Tanana Terrane in Little Kalzas Lake area consists of a lower quartzite package and an upper metavolcanic package. The lower quartzite package includes a discontinuous metavolcaniclastic and mafic metavolcanic unit. The upper metavolcanic package consists predominantly of intermediate to felsic metavolcanic rocks in the northern part of the map area. These rocks pass southward into a clastic-dominated metavolcanic assemblage. A conspicuous crinoidal marble occurs in the middle of the upper metavolcanic package and can be traced between the northern and southern domains.

The layered metamorphic rocks are intruded by the multi-phase Little Kalzas orthogneiss complex in the northeastern part of the map area along the southwestern side of Tintina Trench. The Little Kalzas orthogneiss complex, of uncertain age, comprises granodioritic to granitic gneiss and contains abundant xenoliths of country rock. Younger (Jurassic?), post-kinematic quartz monzonite (in the north) to quartz-diorite (in the south) plutons also intrude the area. The youngest intrusive rocks are small plugs of Tertiary quartz-feldspar porphyry.

A pervasive transposition foliation and mineral lineation are developed throughout the area, except in local low-strain domains where primary textures are preserved. The transposition foliation is axial-planar to tight south southwest-vergent folds whose axial surfaces become progressively upright to south southwest-dipping toward the northeast. These structures are deformed by younger crenulation cleavages and associated open folds.

RÉSUMÉ

Dans la région du lac Little Kalzas, le terrane de Yukon-Tanana est formé d'un assemblage inférieur de quartzite et d'un assemblage supérieur de roches métavolcaniques. L'assemblage inférieur de quartzite contient une unité métavolcanoclastique discontinue qui inclue des roches métavolcaniques mafiques. Dans la partie septentrionale de la région, l'assemblage supérieur est composé essentiellement de roches métavolcaniques intermédiaires à felsiques qui passent vers le sud à un assemblage à dominante métavolcanoclastique. Du marbre à crinoïdes est visible dans la partie médiane de l'assemblage métavolcanique supérieur; on peut le retracer entre les domaines septentrionaux et méridionaux.

Les roches métamorphiques stratifiées sont pénétrées par le complexe d'orthogneiss polyphasé de Little Kalzas qui s'est mis en place dans le nord-est de la région cartographiée, le long de la bordure sud-ouest du sillon de Tintina. Le complexe d'orthogneiss de Little Kalzas, d'âge incertain, contient des gneiss granodioritiques à granitiques qui renferment d'abondants xénolites de la roche encaissante. Des plutons postorogéniques, d'âge plus récent (Jurassique?), allant des monzonites quartzifères (dans le nord) à des diorites quartzifères (dans le sud) sont aussi présents dans la région. Les roches intrusives les plus récentes sont de petits dômes de porphyres à quartz et feldspaths d'âge Cénozoïque.

À l'exception de domaines locaux légèrement déformés où les textures primaires ont été préservées, la région est caractérisée par une schistosité pénétrative de transposition et une linéation minérale. La schistosité de transposition est de plan axial à des plis fermés à vergence sud-sud-ouest, lesquels, vers le nord-est, deviennent progressivement droits, puis s'inclinent vers le nord-nord-est. Ces structures sont déformées par des clivages de crénulation qui sont de plan axial à des plis ouverts.

INTRODUCTION

This report presents preliminary results from 1:50 000-scale bedrock mapping of Little Kalzas Lake area (105L/13) initiated during the summer of 1998 (Colpron, 1998). Little Kalzas Lake area occupies the northwest corner of the Glenlyon map area, which was previously mapped at the scale of 1:253 440 by Campbell (1967). Campbell's work identified a 30-50 km-wide, northwest-striking belt of metasedimentary, metavolcanic and metaplutonic rocks southwest of Tintina Trench in the centre of Glenlyon map area which has been correlated with Yukon-Tanana Terrane (Fig. 1; Tempelman-Kluit, 1979; Coney et al., 1980; Wheeler et al., 1991). Restoration of 450 km of dextral displacement along Tintina Fault juxtaposes this belt of rocks with Yukon-Tanana Terrane rocks in the Finlayson Lake area in which numerous volcanic-hosted massive sulphide deposits and occurrences have been recently found (e.g., Kudz Ze Kayah, Wolverine; Hunt, 1997). These new discoveries have increased the need for a better understanding of the stratigraphy and tectonic evolution of the terrane as a whole but in particular of nearby areas about which little is known, such as Little Kalzas Lake area.

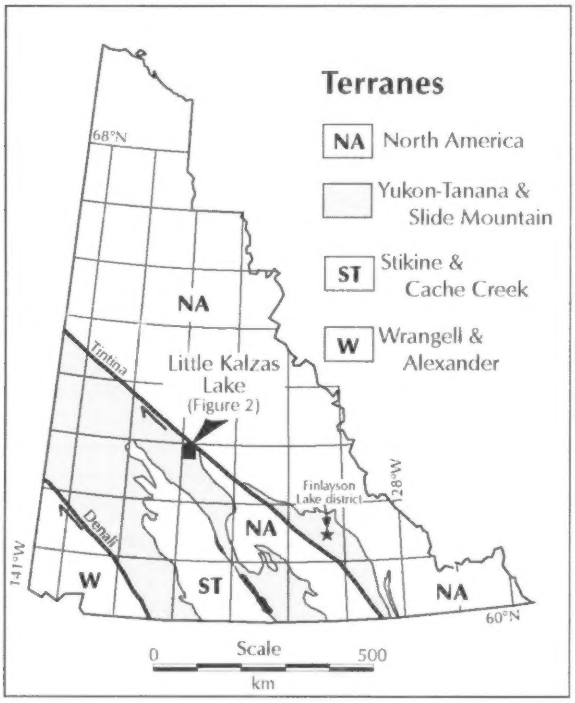

Figure 1. *Location of the Little Kalzas Lake area with respect to distribution of Yukon-Tanana Terrane in the Yukon and to syngenetic sulphide deposits of the Finlayson Lake district.*

STRATIGRAPHY

The regional stratigraphy of Yukon-Tanana Terrane in Little Kalzas Lake area comprises a lower quartzite package (Unit 1) and an upper metavolcanic package (Units 2 and 4) containing a conspicuous marble marker (Unit 3). Up to nine mappable units were identified in alpine exposures along ridges north of Macmillan River. However, only a four-fold subdivision of the layered rocks could be traced into the heavily forested areas which cover much of the Little Kalzas Lake area.

Metasedimentary and metavolcanic rocks in the area generally are pervasively deformed (strongly foliated and lineated) and metamorphosed to greenschist facies. Although pristine primary textures are preserved sporadically, the facing direction of the stratigraphic sequence could not be determined with certainty. Therefore, stratigraphic units are described below according to their structural position (assuming an upright stratigraphic sequence prior to dominant regional deformation). This stratigraphic sequence is provisional and most likely will be revised after further field, biostratigraphic and geochronologic studies are completed.

UNIT 1 (QUARTZITE UNIT)

The lowest stratigraphic unit in Little Kalzas Lake area consists predominantly of massive to well-bedded quartzite (Figs. 2 and 3). The quartzite commonly displays white to medium grey wispy banding. It is progressively more micaceous up-section, where it is commonly intercalated with dark grey phyllite. North of Macmillan River, primary layering in the quartzite is generally obliterated by the dominant foliation. On Pelmac Ridge, the quartzite typically occurs in beds 10 to 40 cm thick (Fig. 2).

The quartzite unit includes a middle metavolcaniclastic unit (Unit 1v) around Dillweed Plateau (informal name; see Fig. 4). The metavolcaniclastic unit consists primarily of light green chloritic phyllite intercalated with light green quartzite and feldspathic grit. Minor greenstone and felsic schist occur within the metavolcaniclastic unit along the east flank of Dillweed Plateau. Brown weathering dolomitic lenses are common within the chloritic phyllite and greenstone. Along the southern margin of Dillweed Plateau, phyllite of the metavolcaniclastic unit is locally intercalated with coarse-grained metadiorite of the Dillweed orthogneiss (unit Mgd, Fig. 4). The metavolcaniclastic unit passes eastwardly into a mixture of dark grey to dark green phyllite and thin horizons (< 1 m) of dark grey quartz grit which are indistinguishable from dark grey quartzite and phyllite of Unit 1 to the southeast.

South of Pelmac Ridge, the quartzite is inferred to pass laterally into coarse-grained dolomitic grit and beige weathering, medium to dark grey quartz-muscovite-dolomite schist[1] (Unit 1gr; Fig. 4). Dark grey dolomitic quartzite and minor light

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[1] In naming metamorphic rocks, the constituent minerals are listed in decreasing order of relative abundance.

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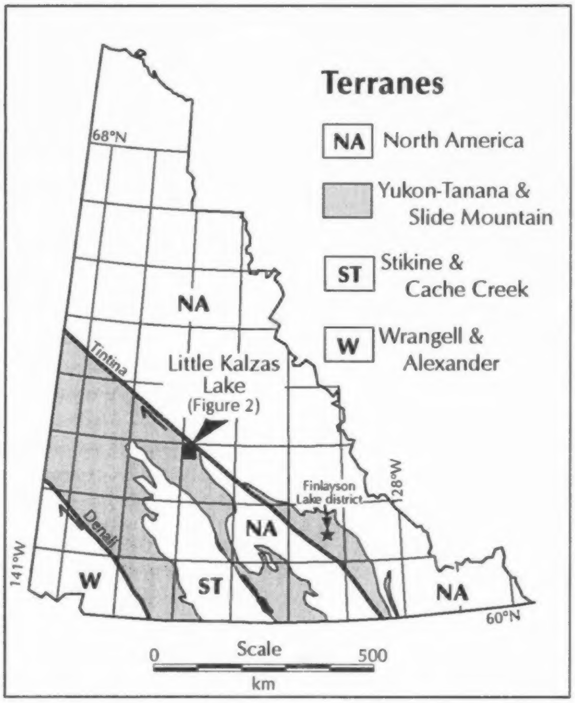

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South of Pelmac Ridge, the quartzite is inferred to pass laterally into coarse-grained dolomitic grit and beige weathering, medium to dark grey quartz-muscovite-dolomite schist[1] (Unit 1gr; Fig. 4). Dark grey dolomitic quartzite and minor light green quartz-muscovite-chlorite-dolomite (± biotite) schist are also intercalated with the grit and beige dolomitic schist that dominates Unit 1gr. The ubiquitous presence of dolomite distinguishes this unit from other map units in the area. The contact with the surrounding massive quartzite is not exposed and, therefore, the exact nature of the relationship between Unit 1gr and the quartzite of Unit 1 is unknown. Unit 1gr probably extends eastward along the north shore of Pelly River (Campbell, 1967, p. 41).

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[1] In naming metamorphic rocks, the constituent minerals are listed in decreasing order of relative abundance.

UNIT 2 (LOWER METAVOLCANIC UNIT)

Unit 1 is transitionally overlain by a lithologic assemblage which is dominated by rocks of volcanic parentage (Unit 2). North of Macmillan River, the base of Unit 2 corresponds to a sequence of intercalated tan weathering, "waxy," quartz-muscovite-feldspar (± chlorite) schist (felsic metavolcanic rock), carbonaceous phyllite and minor gritty quartzite (Unit 2fv). A light grey to white, finely recrystallized marble occurs near the top of Unit 2fv. The marble is intercalated with dark grey to black phyllite and dark green chloritic phyllite.

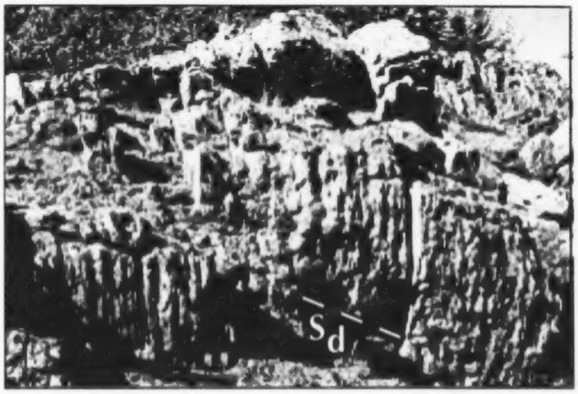

Figure 2. *Well-bedded quartzite (Unit 1), Pelmac Ridge. View is to the west, with dominant foliation (Sd) dipping shallowly to the north. Hammer at left-centre for scale.*

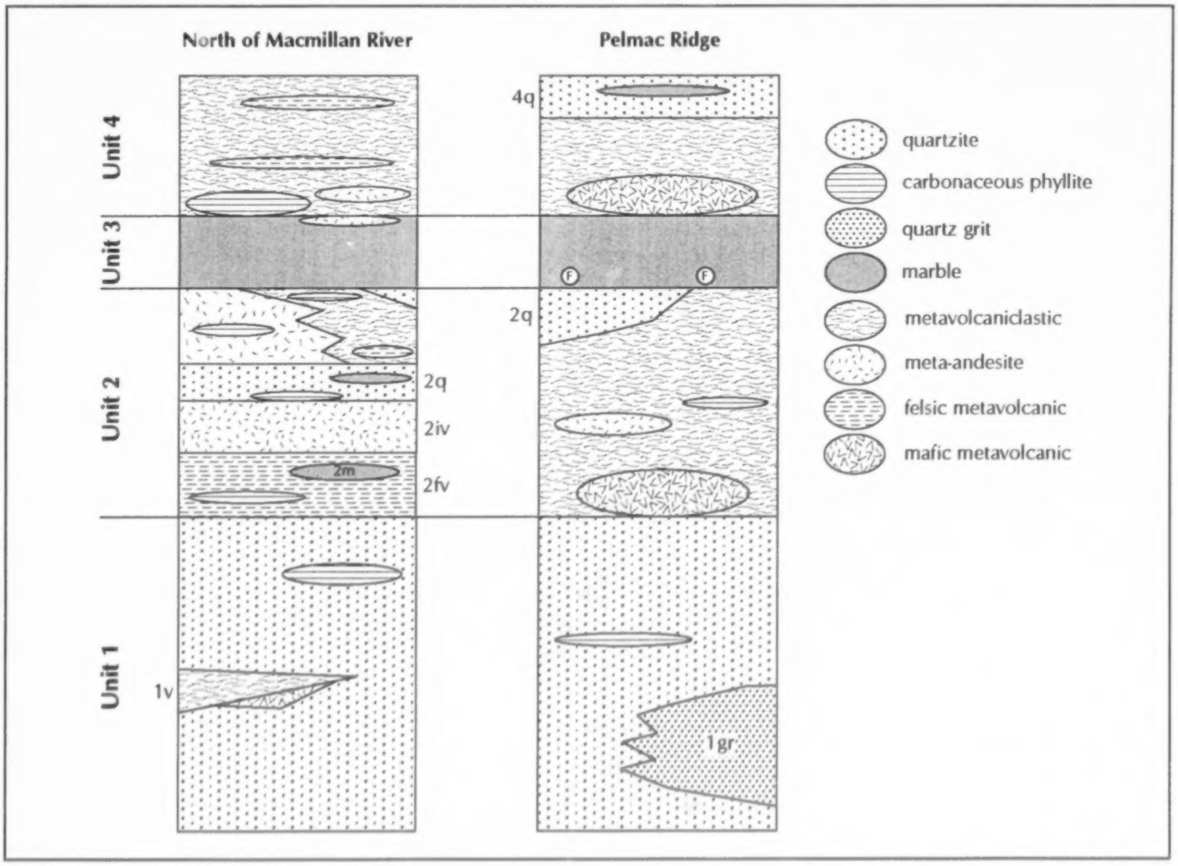
North of Macmillan River
Pelmac Ridge
Unit 4
Unit 3
Unit 2
Unit 1
4q
2q
2q
2iv
2fv
2m
1v
1gr
F
F
quartzite
carbonaceous phyllite
quartz grit
marble
metavolcaniclastic
meta-andesite
felsic metavolcanic
mafic metavolcanic

Figure 3. *Schematic representation of stratigraphic relations in the Little Kalzas Lake area. (Symbols shown in Fig. 4.)*

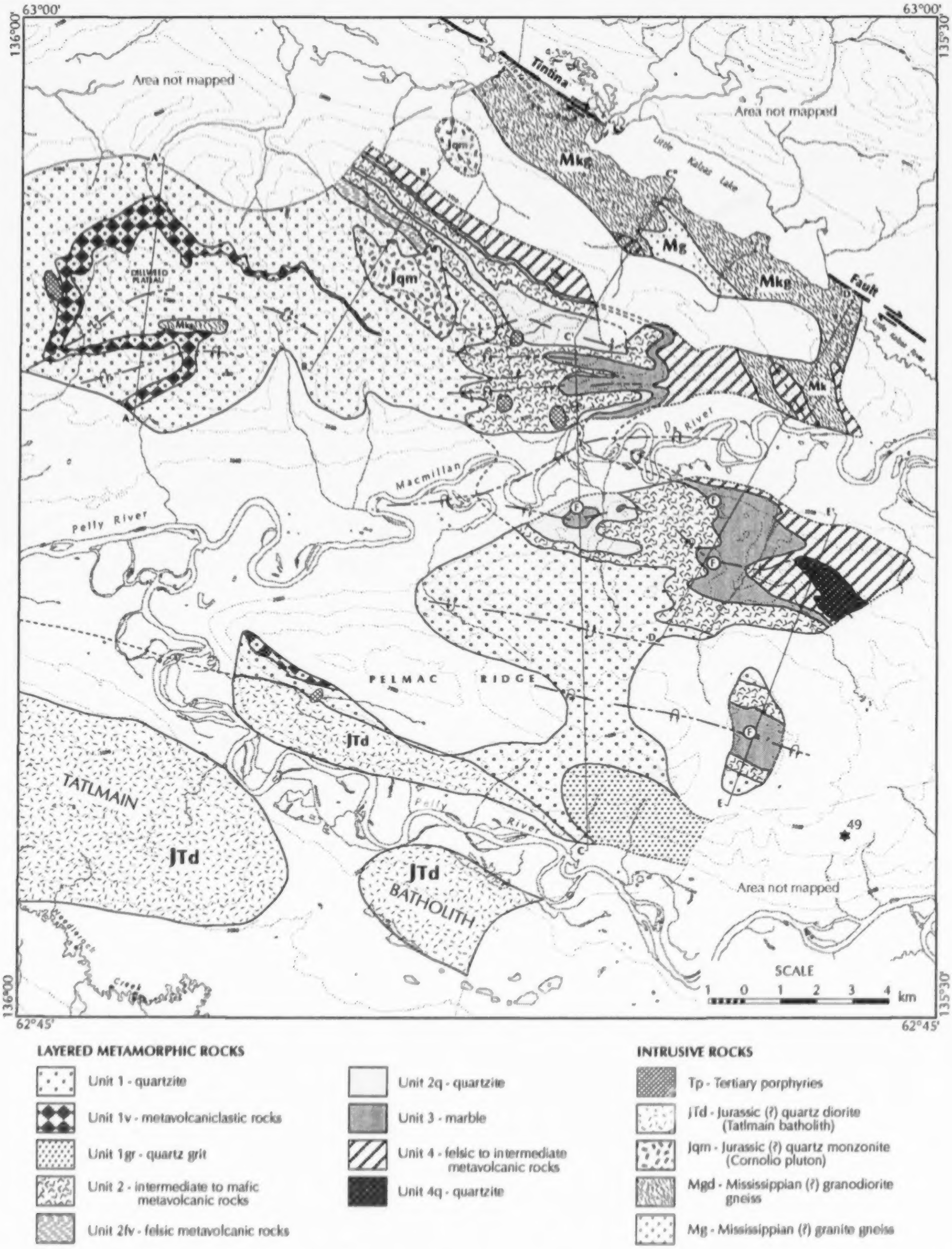
63°00'
136°00'
63°00'
135°30'
Area not mapped
Area not mapped
Tintina
Fault
Little Kalzas Lake
Mkg
Mg
Mk
Jqm
A
A'
B
B'
C
C'
D
D'
E
E'
F
Macmillan River
Pelly River
PELMAC RIDGE
JTd
TATLMAIN
BATHOLITH
Pelly River
49
Area not mapped
SCALE
1 0 1 2 3 4 km
136°00'
62°45'
135°30'
62°45'
LAYERED METAMORPHIC ROCKS
Unit 1 - quartzite
Unit 1v - metavolcaniclastic rocks
Unit 1gr - quartz grit
Unit 2 - intermediate to mafic metavolcanic rocks
Unit 2fv - felsic metavolcanic rocks
Unit 2q - quartzite
Unit 3 - marble
Unit 4 - felsic to intermediate metavolcanic rocks
Unit 4q - quartzite
INTRUSIVE ROCKS
Tp - Tertiary porphyries
JTd - Jurassic (?) quartz diorite (Tatlmain batholith)
Jqm - Jurassic (?) quartz monzonite (Cornolio pluton)
Mgd - Mississippian (?) granodiorite gneiss
Mg - Mississippian (?) granite gneiss

Figure 4. *Geological map of the Little Kalzas Lake area (105L/13). F = occurrences of crinoidal marble in Unit 3. Number 49 indicates location of mineral occurrence 105L 049 (Hugh, Gal; Yukon Minfile). Straight lines between letters are location of cross sections shown in Figure 5.*

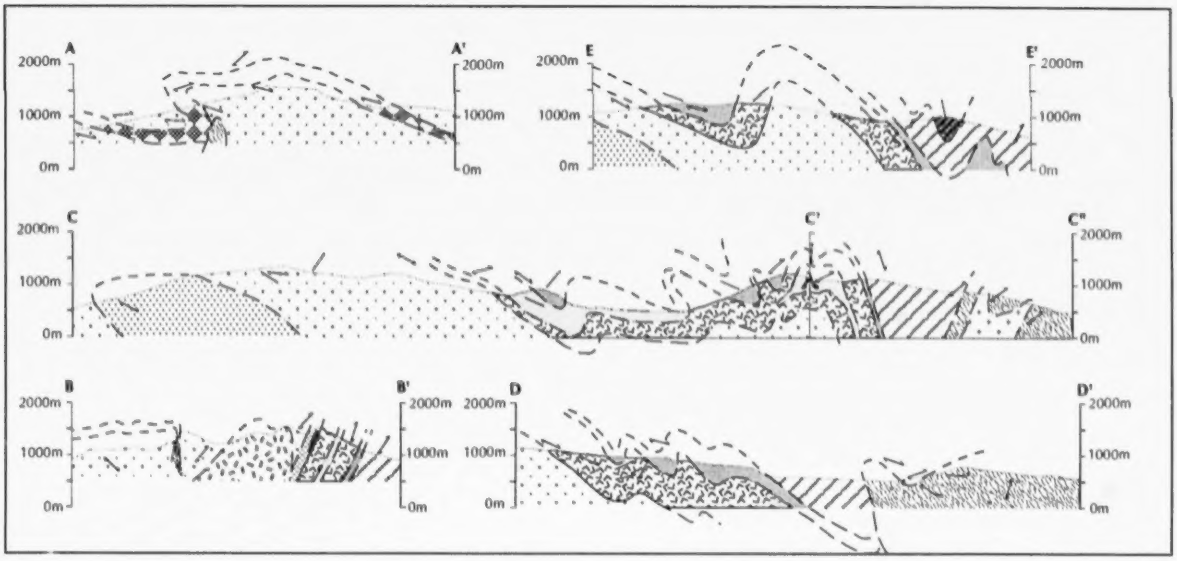

Figure 5. *Vertical cross sections for the Little Kalzas Lake area. Line of sections and legend are located in Figure 4.*

The most prominent rock type in Unit 2, north of Macmillan River, is massive to foliated, dark green to black, fine-grained plagioclase-epidote-hornblende-biotite-calcite meta-andesite (Unit 2iv, Fig. 3). The meta-andesite is commonly plagioclase-phyric (Fig. 6) and typically contains disseminated pyrite. Quartzo-feldspathic and/or epidote-rich segregations locally occur within the meta-andesite. A white to dark grey cherty quartzite and minor dark grey phyllite unit (Unit 2q) occurs in the middle of the meta-andesite. The quartzite is typically less than 100 m thick along alpine ridges; it apparently thickens to the east, where it is poorly exposed in a heavily forested valley. There, a white marble occurs within the quartzite in the core of an upright antiform (Figs. 4 and 5). Above the quartzite, the meta-andesite is intercalated with dark grey phyllite and passes eastward into a tan weathering, light grey, calcareous muscovite-chlorite phyllite and minor felsic quartz-muscovite-feldspar schist (Fig. 3).

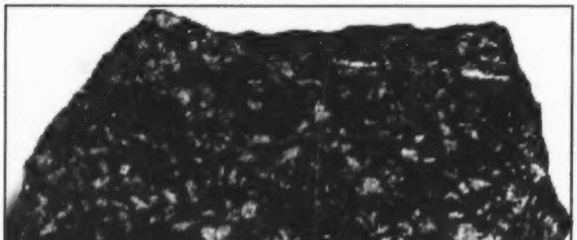

Figure 6. *Plagioclase-phyric meta-andesite (Unit 2). Hand sample is approximately 5 cm across.*

Near Macmillan River, and on Pelmac Ridge to the south, Unit 2 is dominated by light to medium green, muscovite-quartz-chlorite phyllite and micaceous quartzite (metavolcaniclastic rocks) with minor intermediate to mafic metavolcanic rocks and felsic quartz-muscovite-feldspar schist. On Pelmac Ridge, the metavolcanic rocks of Unit 2 include a massive, feldspar-sericite-biotite-titanite schist which contains lapilli-sized clasts of chlorite-calcite-plagioclase up to 3 cm long. The top of Unit 2 locally is marked by a foliated white to medium grey quartzite intercalated with 1-5 mm thick beds of dark grey carbonaceous phyllite. Elsewhere, metavolcanic rocks that underlie marble of Unit 3 are typically calcareous.

UNIT 3 (MARBLE)

A conspicuous laterally persistent marble divides metavolcanic rocks of Unit 2 from those of Unit 4 (Fig. 3). The marble is typically light grey to white and locally weathers to a light buff colour. Near Macmillan River, the marble occurs in large masses in the hinge zone of folds. It commonly contains well-preserved crinoids (meta-packstone; Fig. 7) and is locally cherty. North of Macmillan River, the marble is much thinner and extensively recrystallized. It is locally phyllitic and closely associated with meta-andesite and carbonaceous phyllite.

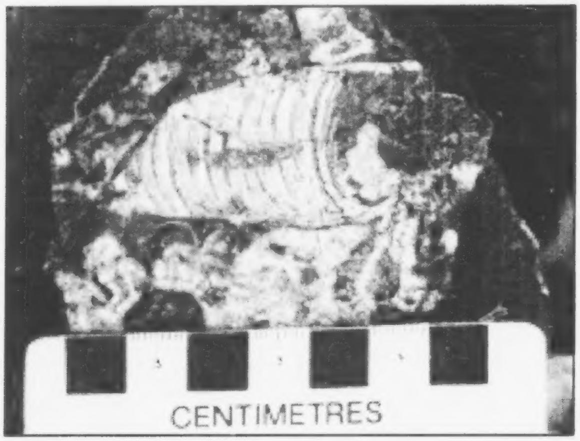

Figure 7. *Well preserved crinoid from marble (Unit 3), south of Macmillan River.*

UNIT 4 (UPPER METAVOLCANIC UNIT)

Unit 4 is generally poorly exposed and comprises a mixture of metasedimentary and metavolcanic rocks. North of Macmillan River, Unit 4 includes carbonaceous phyllite and quartzite, meta-andesite and felsic metavolcanic rocks. The felsic schist is most prominent along the slopes on the north side of Macmillan River. It is a light grey to light green, "waxy" muscovite-quartz-feldspar schist which locally contains millimetre-scale quartz and feldspar augen. On Pelmac Ridge, Unit 4 is dominated by light green quartz-muscovite-chlorite phyllite and light green quartzite and grit (metavolcaniclastic rocks) intercalated with minor intermediate to mafic metavolcanic rocks. There, the lower part of Unit 4 is a massive chlorite-epidote-actinolite-plagioclase schist (greenstone). The highest stratigraphic unit consists of white, green and pink dolomitic quartzite intercalated with 0.5-5 cm-thick brown weathering dolomitic beds (Unit 4q; Fig. 4).

INTRUSIVE ROCKS

The layered metamorphic rocks are intruded by at least three suites of intrusive rocks. The oldest suite is penetratively deformed with the country rocks; the two younger suites postdate deformation.

In the northeastern part of the map area, along the southwestern side of Tintina Trench, the multi-phase Little Kalzas orthogneiss complex, of uncertain age (possibly Mississippian), comprises an older granodioritic gneiss (Mgd) which is intruded by a granitic gneiss (Mg). Both phases contain abundant xenoliths of country rock. The granodioritic gneiss (Mgd) is typically a medium to dark green, fine- to medium-grained, chlorite-epidote-plagioclase-quartz-biotite ± hornblende ± K-feldspar ± muscovite ± tourmaline gneiss. Near Macmillan River, the granodioritic gneiss commonly contains K-feldspar megacrysts (Fig. 8). It occurs as a sill complex within the metasedimentary and metavolcanic rocks of Unit 4. The granodioritic gneiss is massive to strongly foliated, the foliation being most penetrative at the margin of individual sills. The granodioritic gneiss is intruded by a strongly foliated, coarse-grained, quartz-plagioclase-chlorite-epidote-biotite granitic to tonalitic gneiss (Mg). Disseminated pyrite occurs in all phases of the Little Kalzas orthogneiss complex and within xenoliths of country rock.

A small body of meta-igneous rocks of uncertain age (Mississippian?) intrudes metasedimentary and metavolcanic rocks of Unit 1 along the south flank of Dillweed Plateau (Dillweed orthogneiss, Mgd; Fig. 4). The Dillweed orthogneiss is a medium grey to medium green, medium to coarse-grained, plagioclase-chlorite-muscovite-quartz ± biotite ± K-feldspar porphyritic quartz diorite to granodiorite gneiss. The orthogneiss is strongly foliated and locally intercalated with light green chlorite-muscovite-quartz phyllite of Unit 1v, suggesting that the orthogneiss was perhaps a subvolcanic intrusion.

The post-kinematic Cornolio pluton (informal name; 5.5 km SW of Little Kalzas Lake) intrudes the layered metamorphic rocks in the north-central part of the map area (Jqm; Fig. 4). It is an unfoliated to weakly foliated medium-grained hornblende ± biotite quartz monzonite. A few isolated outcrops of medium- to coarse-grained, hornblende quartz monzonite also occur along

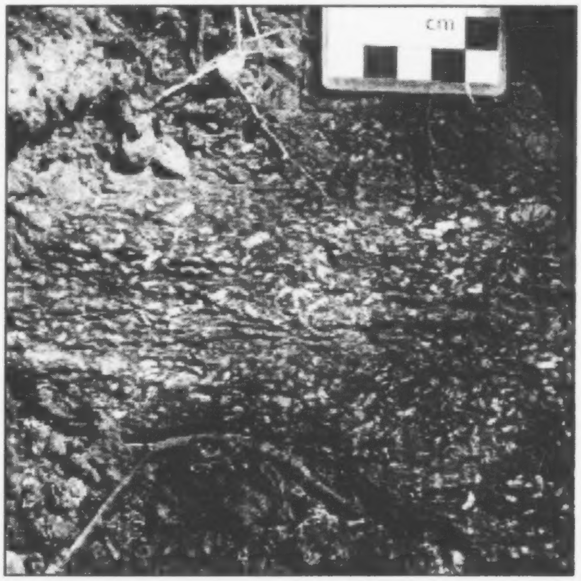

Figure 8. *Foliated, K-feldspar megacrystic orthogneiss, Little Kalzas orthogneiss complex, near Macmillan River.*

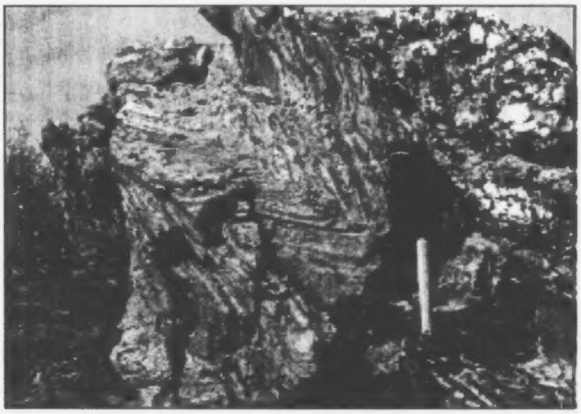

Figure 9. *South southwest-verging fold in metavolcaniclastic rocks of Unit 2, Pelmac Ridge. View to the northwest.*

a creek about 3 km north of the main body of the Cornolio pluton (Fig. 4). In that locality, hornblende defines a weak foliation which is probably of magmatic origin. Country rocks in the metamorphic aureole of the main body of the Cornolio pluton contain cordierite (± sillimanite) indicating that the pluton was emplaced at high level in the crust. The age of the Cornolio pluton is uncertain.

The southwest corner of the map area is underlain by the Tatlmain batholith (Tempelman-Kluit, 1984; JTd, Fig. 4). It is composed of medium- to coarse-grained, equigranular hornblende ± biotite quartz diorite. A Jurassic age is assigned to the Tatlmain batholith based on similarity in composition with the Tatchun batholith in the southern part of Glenlyon map area (Campbell, 1967) which yielded Middle Jurassic K-Ar dates from hornblende and biotite (Tempelman-Kluit, 1984).

The youngest intrusive rocks in Little Kalzas Lake area are small plugs of quartz-feldspar porphyry (Tp; Fig. 4). Three types of porphyries are recognized based on their colour and composition and abundance of phenocrysts. The most common type of quartz-feldspar porphyry is pink to reddish-brown in colour, and contains up to 30% plagioclase (5 mm) and smoky quartz (< 2 mm) phenocrysts. This pink porphyry occurs in four small bodies, 100-400 m in diameter, in the north-central part of the map area (Fig. 4), one of which yielded a U-Pb zircon date of 55 ± 1.7 Ma (Mortensen and Jackson, unpublished). West of Dillweed Plateau, and at one locality north of Cornolio pluton, a grey rhyolite porphyry contains < 10% micro-phenocrysts (< 1 mm) of smoky quartz and plagioclase. Finally, a white quartz-feldspar ± biotite porphyry containing up to 60-70% phenocrysts intrudes the contact between the Tatlmain batholith and micaceous quartzite and carbonaceous phyllite (Unit 1) at the western end of Pelmac Ridge (Fig. 4).

STRUCTURE

The dominant tectonic fabric in the area is a pervasive transposition foliation and mineral lineation. Although primary layering has generally been transposed parallel to foliation, primary textures are preserved in local low-strain domains (e.g., Figs. 6 and 7). The intense deformation recorded by the dominant structures has not disrupted the stratigraphic sequence at the scale of the map area (Fig. 4), in contrast to regional models previously suggested for Yukon-Tanana Terrane (e.g., Tempelman-Kluit, 1979).

The transposition foliation is axial-planar to tight, gently west northwest- or south southeast-plunging, south southwest-verging folds (Figs. 5 and 9). The foliation and axial surfaces progressively change toward the northeast from NNE-dipping to upright to south southwest-dipping (Fig. 6). Locally, the dominant folds deform a schistosity suggesting that an older deformation event affected the area. However, the regional significance of this older deformation event has yet to be established.

A mineral lineation, defined by orientation of elongate minerals (primarily micas and quartz) on planes of the dominant foliation, is generally parallel to fold axes and bedding/foliation intersections. It is commonly a penetrative quartz rodding in massive quartzite on Dillweed Plateau where the mineral lineation constitutes the dominant fabric element.

The dominant structures are deformed by a younger crenulation cleavage which strikes to the northwest and dips moderately to the northeast. This crenulation cleavage is axial-planar to broad open folds (Fig. 10) which plunge gently to the southeast (together with the crenulation lineation). These open folds have only limited regional significance; they are responsible for the broad doming of the dominant foliation near Dillweed Plateau.

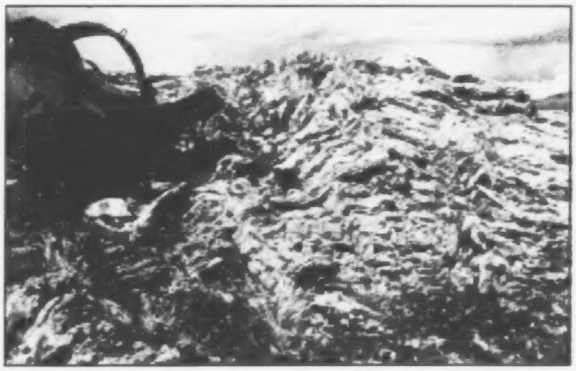

Figure 10. *Broad open fold of the dominant foliation in micaceous quartzite of Unit 1, east of Dillweed Plateau.*

The dominant south southwest vergence of the major structures in Little Kalzas Lake area differs from recent structural interpretations proposed for the Teslin zone, approximately 150 km to the southeast, where major structures have a predominant northeast vergence (e.g., Gallagher et al., 1998; de Keijzer et al., in press). However, the style of deformation recorded in Little Kalzas Lake area is consistent with that of the Big Salmon Complex farther south, near the 60th parallel, where major folds are southwest- and west southwest-verging (Mihalynuk et al., 1998). At this stage, our limited knowledge of the regional geology of Yukon-Tanana Terrane precludes a proper resolution of the apparent variability in the style and orientation of deformational features reported from various locations along strike.

MINERAL OCCURRENCES

Only a single Yukon Minfile occurrence is present in the Little Kalzas Lake area southwest of Tintina Fault (Yukon Minfile, 105L 049; Hugh, Gal; Fig. 4). This occurrence was delineated on the basis of an airborne magnetic anomaly and subsequently examined for base metal and gold mineralization (Sheldrake, 1986). Inconclusive results from geochemical and VLF-EM surveys did not justify further work on this occurrence. Although there is no exposure in the area, the magnetic anomaly is most likely hosted in quartzite of Unit 1 (Fig. 4).

No new mineralization was encountered during mapping of Little Kalzas Lake area. However, the occurrence of altered felsic schist (light green in colour) in Unit 4 along the slopes north of Macmillan River (UTM Zone 8, 467222E, 6976148N), and the local abundance of pyrite in the same area, require further investigation.

DISCUSSION

Although with important differences, the stratigraphy and structural style of the rocks of Little Kalzas Lake area are similar to those of Yukon-Tanana Terrane across Tintina Trench. Precise correlation between the rocks of Little Kalzas Lake area and those elsewhere in Yukon-Tanana Terrane cannot be attempted until the necessary geochemical, biostratigraphic, and geochronological studies have been done. However, some general statements can be made on the basis of field relationships.

- The occurrence of voluminous clean quartzite is perhaps one of the most distinguishing characteristics of the stratigraphic sequence mapped in Little Kalzas Lake area (Figs. 3 and 4). Clean quartzite is a relatively uncommon lithology in Yukon-Tanana Terrane; it is a minor constituent of the Nasina assemblage west of Dawson, approximately 280 km to the northwest (Mortensen, 1988a, 1988b; 1992). The presence of clean quartzite in Little Kalzas Lake area therefore suggests a possible correlation with the Nasina assemblage of west-central Yukon.
- The crinoidal marble of Unit 3 is the most promising horizon for stratigraphic linkage with other parts of Yukon-Tanana Terrane. Latest Mississippian to Early Permian fossiliferous marble occurs sporadically throughout Yukon-Tanana Terrane (cf. Mortensen, 1992; his Fig. 5). Latest Mississippian marble occurs below an important unit of mafic to intermediate metavolcanic rocks in the Big Salmon complex of northern British Columbia and the southern Yukon (Mihalynuk et al., 1998). Upper Paleozoic marble is also present in the Finlayson Lake district (Tempelman-Kluit, 1977; Mortensen, 1992). Several samples of Unit 3 marble are being analyzed for microfossils. If the Unit 3 marble yields a Late Mississippian-Pennsylvanian age, then the upper metavolcanic sequence (Units 2 and 4) of Little Kalzas Lake area is most likely coeval with the upper part of Yukon-Tanana stratigraphy (which hosts the Wolverine deposit) as defined by Murphy and Piercey (this volume) in the Finlayson Lake District.

IMPLICATIONS FOR MINERAL EXPLORATION

The recognition of bimodal felsic and mafic metavolcanic rocks in Little Kalzas Lake area has obvious implications for the mineral potential of the area. It affirms some correlation with the rocks of the Finlayson Lake massive sulphide belt in Yukon-Tanana Terrane northeast of Tintina Trench, thereby substantially increasing the prospectivity of Yukon-Tanana Terrane southwest of Tintina Trench for these types of deposits. Further indications of massive sulphide potential include altered felsic schist and locally abundant pyrite. Finally, although no massive sulphide mineralization was encountered in the course of mapping of Little Kalzas Lake area, a new occurrence of magnetite-bearing semi-massive sulphide was found in outcrops of altered felsic schist along the Campbell Highway about 95 km along strike to the south (see Colpron, this volume).

SUMMARY

Regional mapping of Little Kalzas Lake area during the summer of 1998 identified a previously unknown stratigraphic succession which includes a lower quartzite sequence (Unit 1) and an upper metavolcanic sequence (Units 2-4). Occurrences of metavolcanic rocks in this area, as well as the discovery of sulphide-bearing horizon in similar rocks farther south, suggests a high potential for the discovery of VMS deposits in Yukon-Tanana Terrane of the Glenlyon map area.

ACKNOWLEDGEMENTS

Alana Rawlings provided cheerful field assistance through dense brush and thick smoke. Many thanks to Belle Murphy for fending off the wild rodents that abound in the central Yukon bush. Brian Parsons (Trans North Helicopters, Carmacks) provided safe flying and was kind enough to act as impromptu expediter. Discussions with Don Murphy, Jim Mortensen, Grant Abbott and JoAnne Nelson continue to improve my understanding of the geology of the northern Cordillera. The manuscript has benefited from a critical review by Don Murphy and editorial advice by Charlie Roots. Jason, Juan and Léon were all sources of inspiration.

REFERENCES

Campbell, R.B., 1967. Geology of Glenlyon map area, Yukon Territory (105 L). Geological Survey of Canada, Memoir 352, 92 p.

Colpron, M., 1998. Preliminary geological map of Little Kalzas Lake area, central Yukon (NTS105L/13). Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, Open File 1998-3, 1:50 000 scale.

Colpron, M., 1999 (this volume). A new mineral occurrence in Yukon-Tanana Terrane near Little Salmon Lake, central Yukon (105L/2). *In:* Yukon Exploration and Geology 1998, C.F. Roots and D.S. Emond (eds.), Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 255-258.

Coney, P.J., Jones, D.L. and Monger, J.W.H., 1980. Cordilleran suspect terranes. Nature, vol. 288, p. 329-333.

de Keijzer, M., Williams, P. F. and Brown, R.L., (in press). Kilometre-scale folding in the Teslin zone, northern Canadian Cordillera, and its tectonic implications for the accretion of the Yukon-Tanana Terrane to North America. Canadian Journal of Earth Sciences.

Gallagher, C.S., Brown, R.L. and Carr, S.D., 1998. A structural re-evaluation of the Teslin Zone, Yukon, Canada. Geological Society of America Abstracts with Program, vol. 30, p. A-177.

Hunt, J.A., 1997. Massive sulphide deposits in the Yukon-Tanana and adjacent terranes. *In:* Yukon Exploration and Geology 1996, Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 35-45.

Mihalynuk, M.C., Nelson, J. and Friedman, R.M., 1998. Regional geology and mineralization of the Big Salmon Complex (104N NE and 104O NW). *In:* Geological Fieldwork 1997, B.C. Ministry of Employment and Investment, Geological Survey Branch, Paper 1998-1, p. 6-1 to 6-19.

Mortensen, J.K., 1988a. Geology of southwestern Dawson map area (NTS 116 B, C). Geological Survey of Canada, Open File 1927, 1:250 000 scale.

Mortensen, J.K., 1988b. Geology of southwestern Dawson map area, Yukon Territory (NTS 116 B, C). *In:* Current Research, Part E, Geological Survey of Canada, Paper 88-1E, p. 73-78.

Mortensen, J.K., 1992. Pre-Mid-Mesozoic tectonic evolution of the Yukon-Tanana Terrane, Yukon and Alaska. Tectonics, vol. 11, p. 836-853.

Murphy, D. and Piercey, S.J., 1999 (this volume). Finlayson project: Geological evolution of Yukon-Tanana Terrane and its relationship to Campbell Range belt, northern Wolverine Lake map area, southeastern Yukon. *In:* Yukon Exploration and Geology 1998, C.F. Roots and D.S. Emond (eds.), Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 47-62.

Sheldrake, R.F., 1986. Report on a ground magnetometer, VLF electromagnetometer and geochemistry survey in the Pelly River area, Yukon Territory. Mineral Resources Directorate, Yukon, Indian and Northern Affairs Canada, Assessment Report# 091813.

Tempelman-Kluit, D.J., 1977. Quiet Lake (105F) and Finlayson Lake (105G) map areas, Yukon Territory. Geological Survey of Canada, Open File 486, 1:250 000 scale.

Tempelman-Kluit, D.J., 1979. Transported cataclasite, ophiolite and granodiorite in Yukon: evidence of arc-continent collision. Geological Survey of Canada, Paper 79-14, 27 p.

Tempelman-Kluit, D.J., 1984. Geology, Laberge (105E) and Carmacks (105I), Yukon Territory. Geological Survey of Canada, Open File 1101, 1:250 000 scale.

Wheeler, J.O., Brookfield, A.J., Gabrielse, H., Monger, J.W.H., Tipper, H.W. and Woodsworth, G.J., 1991. Terrane map of the Canadian Cordillera. Geological Survey of Canada, Map 1713A, 1:2 000 000 scale.

Yukon Minfile. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada. Also available from Hyperborean Productions, Whitehorse, Yukon.

Preliminary stratigraphy and distribution of Devono-Mississippian massive sulphide-bearing volcanic rocks in the Mount Vermilion (Wolf) area, Pelly Mountains (105G/5 and G/6), southeast Yukon

J.A. Hunt
Yukon Geology Program

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ABSTRACT

The Mount Vermilion area is located at the southeast end of the Pelly Mountains volcanic belt, about 90 km southeast of Ross River, and includes the Wolf volcanogenic massive sulphide deposit. This well exposed area was mapped at a scale of 1: 25 000; several stratigraphic sections were measured across the belt. Results from this study show that the southeast end of the belt is made up of dominantly felsic volcaniclastic strata. The base of the succession consists of dominantly brown-pink lapilli tuff interbedded with argillite and lesser trachyte sills/dykes. The middle of the succession is made up primarily of heterolithic lapilli tuff with distinct argillite clasts, maroon matrix tuff with green lapilli-sized fragments and trachyte flows/sills/dykes; the upper part consists of chlorite-altered volcaniclastic rocks containing intermediate dykes and flows. The Wolf deposit is hosted within the middle portion of the volcanic succession proximal to a syenite intrusion.

To the west, towards the centre of the volcanic belt the felsic volcaniclastic component decreases as the number of sills, flows and dykes becomes more numerous, and the amount of intermediate volcanic material increases.

RÉSUMÉ

La région du mont Vermilion est située à l'extrémité sud-est de la ceinture volcanique des monts Pelly, à environ 90 km au sud-est de Ross River et contient l'amas de sulfure massif volcanogène de Wolf. Cette région bien exposée a été cartographiée à l'échelle du 1/25 000; plusieurs coupes stratigraphiques de cette ceinture ont été relevées. Les résultats de la présente étude montrent que l'extrémité sud-est de la zone est constituée principalement de roches volcaniclastiques felsiques. La base de la succession est surtout constituée de tuf à lapilli brun-rose intercalé d'argilite et de sills/dykes à trachyte moins abondants. Le centre de la succession est principalement constitué de tuf hétérolithique à lapilli présentant distinctement des clastes d'argilite, de tuf à matrice brune avec des fragments verts de la taille des lapilli et des coulées/sills/dykes de trachyte; la partie supérieure est constituée de roches volcaniques chloritisées renfermant des dykes et des coulées intermédiaires. Le dépôt de Wolf se trouve au centre de la succession volcanique, près d'une intrusion de syénite.

À l'ouest, vers le centre de la ceinture volcanique, l'élément volcaniclastique diminue au fur et à mesure qu'augmentent le nombre de sills, de coulées et de dykes, ainsi que la quantité de matériaux volcaniques intermédiaires.

INTRODUCTION

The Mount Vermilion area is located in the Pelly Mountains about 90 km southeast of Ross River (Fig. 1). The area lies at the southeast end of the Pelly Mountains volcanic belt (Fig. 2) which hosts several massive sulphide (VMS) occurrences (e.g., Gordey, 1977; Tempelman-Kluit, 1977; Chronic, 1979; Mortensen, 1979, 1981; Doherty, 1997; Holbek and Wilson, 1998; Yukon Minfile 105F 012, 013, 071, 073, 081,105G 008). Initial interest in this belt took place in the 1970s, sparked by exploration of a silver-lead-zinc occurrence known as the MM (Morin, 1977). After several years, the property became dormant, but interest was rekindled by the discovery of the Kudz Ze Kayah and Wolverine deposits in 1994 in time-correlative strata in the Finlayson Lake area immediately to the east (Fig. 1; Schultze, 1996; Tucker et al., 1997). Discovery of VMS mineralization on the Wolf property, at the southeast end of the belt, in 1997 triggered a staking rush and re-assessment of the mineral potential throughout the volcanic belt (Fig. 2; Holbek and Wilson, 1998; Gibson et al., this volume). The belt was mapped at reconnaissance scale by the Geological Survey of Canada (Wheeler et al., 1960a, b; Tempelman-Kluit, 1977a, b; Gordey, 1978 and 1979), with more detailed thesis mapping by Gordey (1977), Chronic (1979) and Mortensen (1979). However, no systematic mapping or stratigraphic study had been carried out in the well exposed Mount Vermilion area which hosts the Wolf deposit. To investigate this area, a field mapping and stratigraphic study was conducted during the 1998 field season. Several additional traverses in the central and northwestern parts of the belt attempted to correlate volcanic stratigraphy throughout the belt. This paper presents results of the study.

REGIONAL SETTING

PELLY-CASSIAR PLATFORM

From Middle Proterozoic through Early Devonian time, a miogeoclinal sequence accumulated along the western margin of North America (Gabrielse and Yorath, 1991). Between mid-

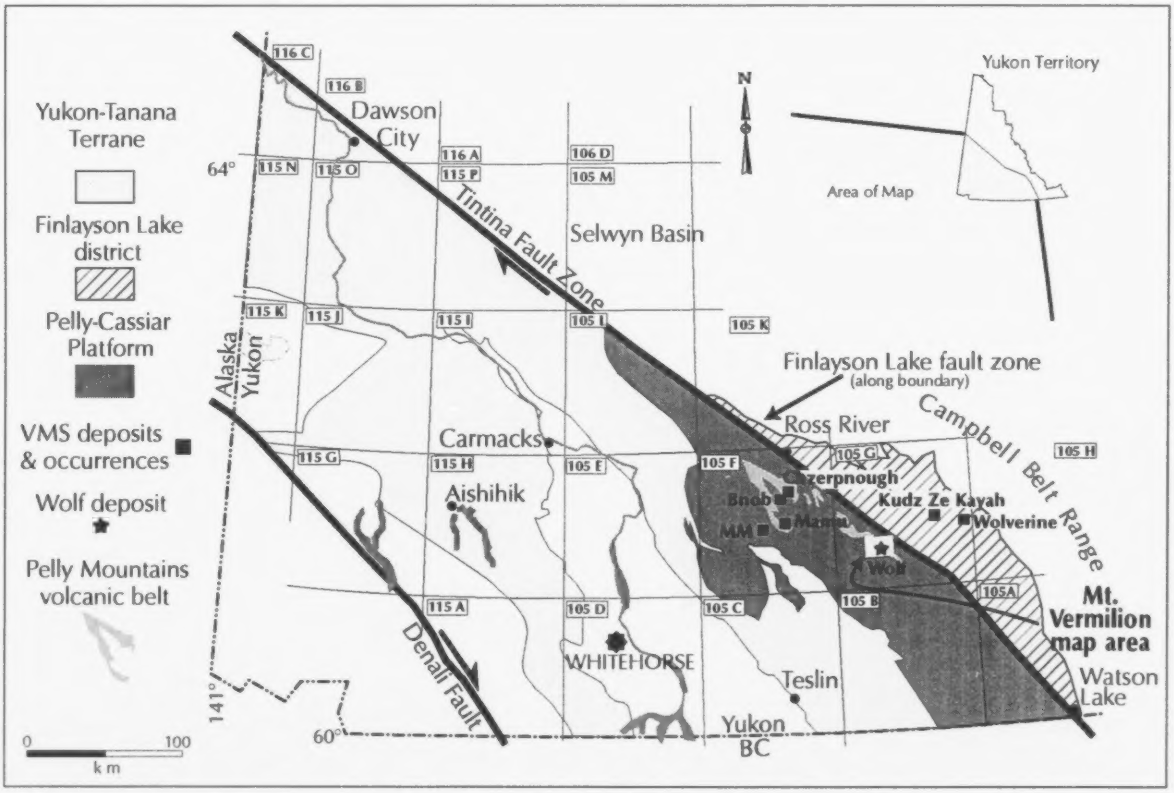
Yukon-Tanana Terrane
Finlayson Lake district
Pelly-Cassiar Platform
VMS deposits & occurrences
Wolf deposit
Pelly Mountains volcanic belt
0
100
km
116 C
116 B
Dawson City
116 A
115 P
106 D
105 M
115 N
115 O
64°
N
Yukon Territory
Area of Map
Tintina Fault Zone
Selwyn Basin
115 K
115 J
115 I
105 L
105 K
Alaska
Yukon
Finlayson Lake fault zone
(along boundary)
Ross River
Campbell Belt Range
Carmacks
115 G
115 H
105 E
105 F
105 G
105 H
Chzerpnough
Bnob
Kudz Ze Kayah
Wolverine
MM
Mamu
Aishihik
Wolf
115 A
105 D
105 C
105 B
105A
Mt. Vermilion map area
Denali Fault
WHITEHORSE
Teslin
Watson Lake
141°
60°
Yukon
BC

Figure 1. Location of the Mount Vermilion area, Pelly-Cassiar Platform, Finlayson Lake district and various VMS deposits and showings. This map is modified from Wheeler and McFeely (1991) and Johnston and Mortensen (1994).

Cambrian and Silurian time, a curvilinear shelf known as the Pelly-Cassiar Platform formed, roughly parallel to the craton edge but separated from it by the Selwyn Basin (Fig. 1; Gabrielse, 1967; Tempelman-Kluit and Blusson, 1977; Mortensen 1981; Fritz et al., 1991). Shallow water deposition on the Pelly-Cassiar Platform continued until Late Devonian time. Block faulting and local uplift during the Late Devonian and Mississippian resulted in deposition of carbonaceous shale and chert pebble conglomerate in the Selwyn Basin and across the Pelly-Cassiar Platform (Blusson, 1976; Gordey, 1978, 1979; Mortensen, 1981). Local explosive volcanism produced thick tuffs and flows whose extremities intertongue with surrounding black shale. Some of these volcanic centres contain base metal mineralization and are the subject of this report. Calcareous argillite of Upper Paleozoic to Triassic age was deposited above the shale and volcanic sequence (Tempelman-Kluit et al., 1976).

PELLY MOUNTAINS VOLCANIC BELT

The Pelly Mountains volcanic belt is arcuate, about 80 km long, up to 25 km wide and forms part of the Pelly-Cassiar Platform (Figs. 1 & 2). The present deformed thickness of the volcanic section is highly variable, ranging from less than 100 m to as much as 1700 m (Gordey, 1977, 1981; Mortensen, 1979, 1981).

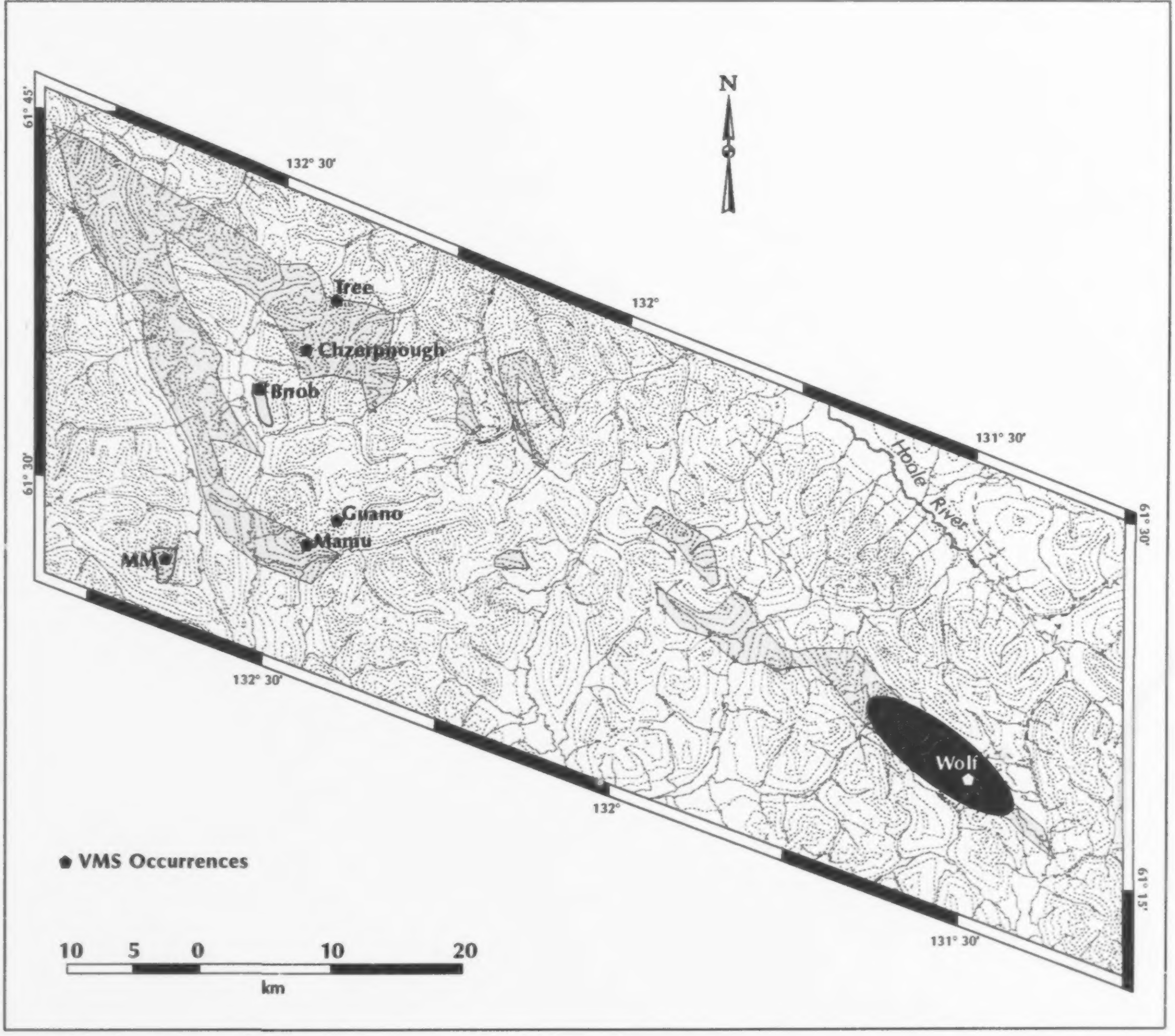

Figure 2. *Location of the Pelly Mountains volcanic belt (light grey area). The Mount Vermilion area lies at the southeast end of the belt. Also shown are the location of VMS occurrences.*

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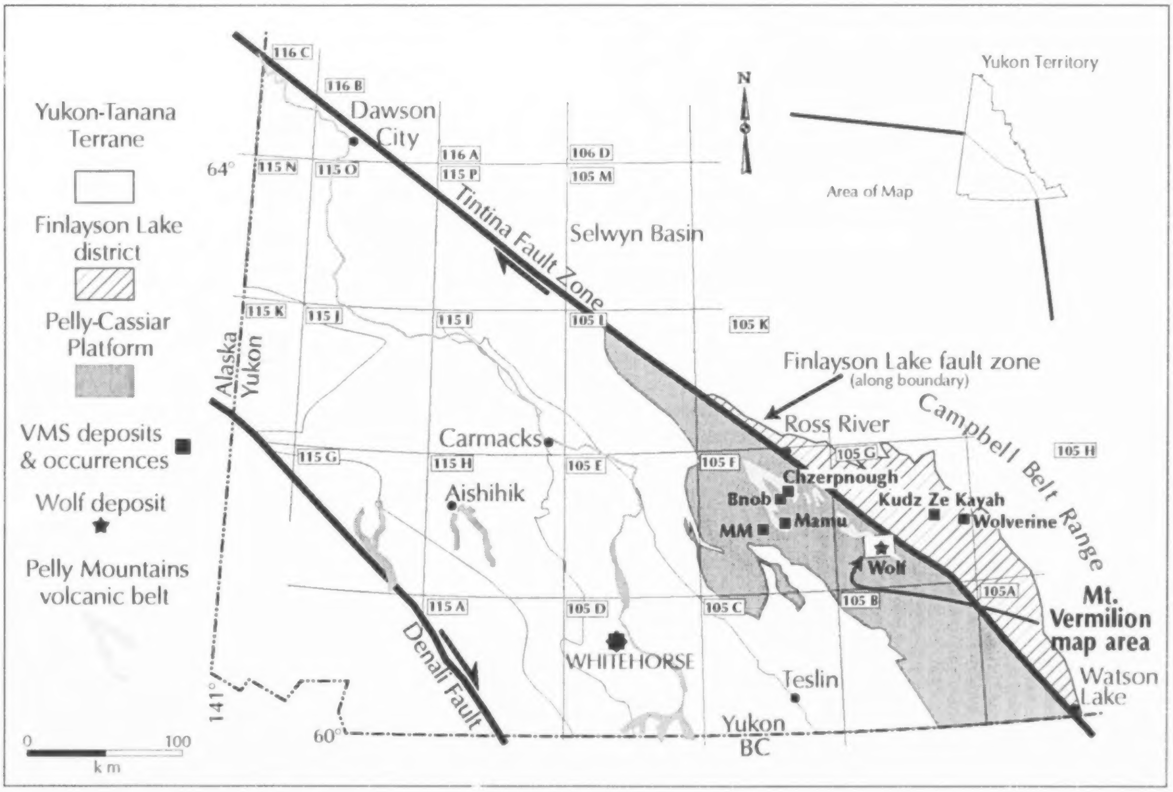
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VMS deposits & occurrences
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116 C
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106 D
64°
115 N
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Area of Map
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115 I
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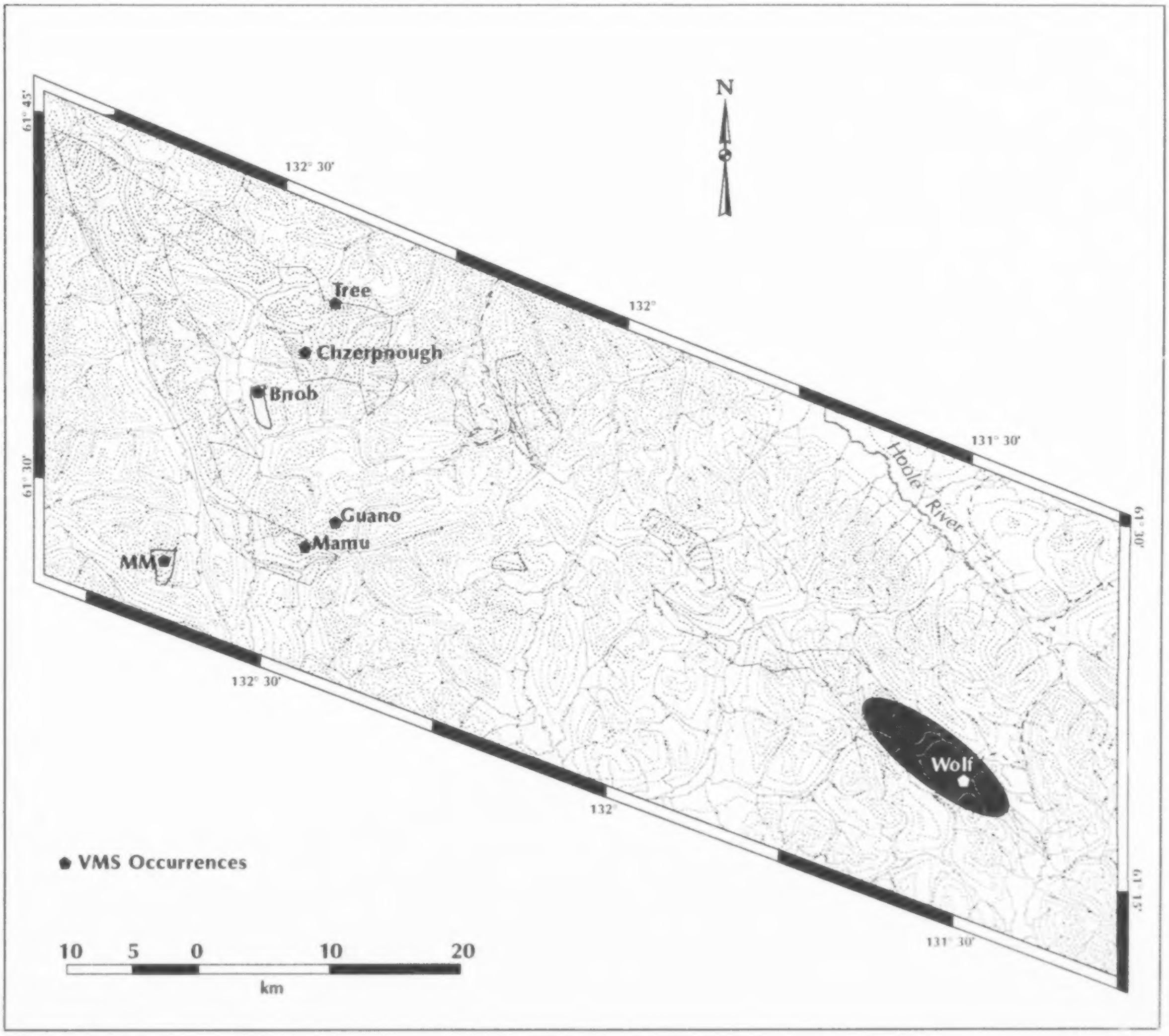


Figure 2. *Location of the Pelly Mountains volcanic belt (light grey area). The Mount Vermilion area lies at the southeast end of the belt. Also shown are the location of VMS occurrences.*

GEOLOGY

In the Mount Vermilion area, at the southeast end of the belt, the volcanic succession is made up primarily of felsic volcaniclastic material with lesser sills/dykes/flows and minor intermediate sills/dykes/flows. At the northwest end of the belt volcanic units of intermediate composition constitute the bulk of the volcanic succession, however, felsic volcanics occur midway through the volcanic sequence. Within these felsic volcanic rocks, Morin (1977) and Mortensen (1979) described several submarine volcanic complexes where extensive volcaniclastic strata are interbedded with flows and tuffaceous chert, and intruded by felsic domes and stocks. These syenitic intrusions were considered by Tempelman-Kluit (1976), Morin (1977) and Mortensen (1979, 1981) to be the subvolcanic equivalent of some of the felsic tuffs and flows. Locally, the felsic tuffs contain pyrite and are immediately overlain by massive sulphide lenses (Morin, 1977; Mortensen, 1979, 1981). Pervasive clay and carbonate alteration characterize the felsic volcanic unit.

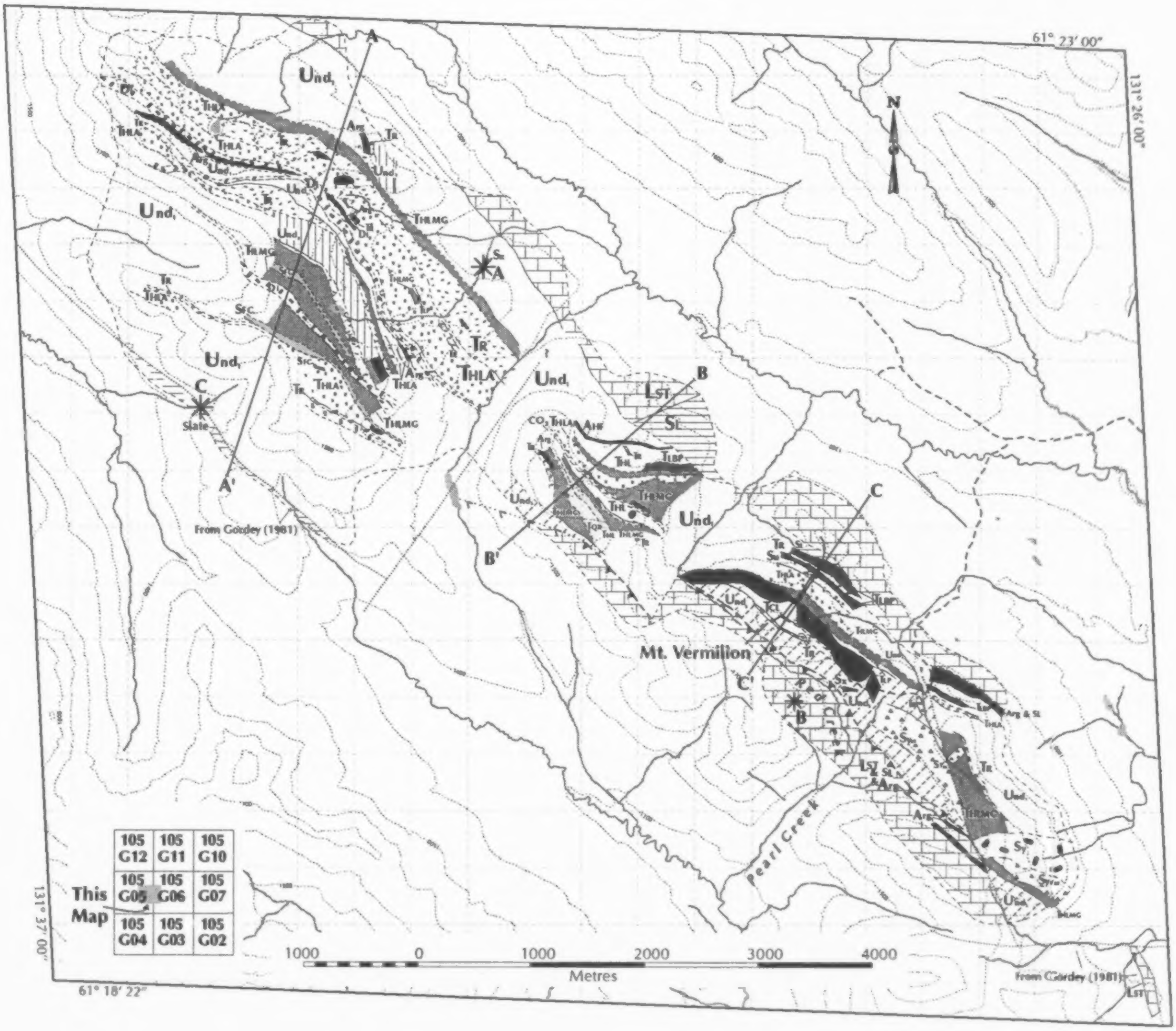
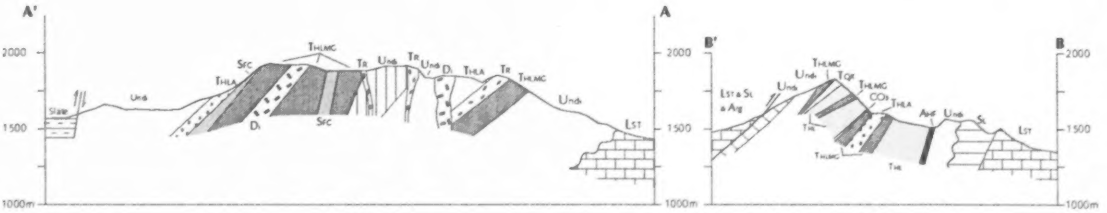
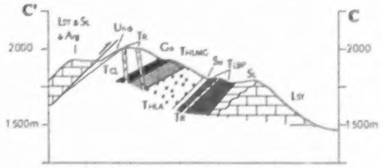

61° 23′ 00″
131° 26′ 00″
131° 37′ 00″
61° 18′ 22″
N
Und.
THLA
TR
THMG
SC
A
A′
B
B′
C
C′
Slate
LST
SL
Mt. Vermilion
Pearl Creek
From Gordey (1981)
1000
0
1000
2000
3000
4000
Metres
105 G12
105 G11
105 G10
105 G05
105 G06
105 G07
105 G04
105 G03
105 G02
This Map

Figure 3. Bedrock geology sketch map of the Mount Vermilion area, Pelly Mountains with some geological contacts taken from Gordey (1981).





MINERAL OCCURRENCES

Yukon Minfile Number	Name	Deposit	Type
105C 008	Wolf	◆	VMS
Previously unreported mineral occurrences			
	A	✹	
	B	✹	
	C	✹	

SYMBOLS

Limit of mapping
Geological contact (defined, approximate, assumed and/or covered)
Fault (defined, approximate, assumed and/or covered)
Thrust fault (defined, approximate, assumed and/or covered)
Bedding — 24 — VERTICAL
Foliation — 67 — VERTICAL
Cross-section line — A — A'
Stratigraphic-section location
Winter trail

LEGEND

DEVONO-MISSISSIPPIAN

Non-fragmental Units

Sy	Syenite - grey weathering, grey to white or rarely pink, very fine-grained to pegmatitic with pink feldspar crystals up to 4 cm long. Disseminations and blebs of pyrite occur throughout the intrusion with rare fluorite.
TR	Trachyte flows, sills and dykes - dark rusty brown to yellow or grey weathering, fresh surfaces are dark pinkish brown to light grey with numerous iron carbonate filled vesicles. Locally fine-grained glassy needle-like feldspar crystals are visible.
Di	Diorite/andesite flows, sills and dykes - medium grey-green to brown weathering with a pitted surface. Fresh surfaces are medium green with relict biotite? and feldspar crystals and trace fine-grained disseminated pyrite. Locally the rocks is cut by numerous carbonate filled fractures.

Fragmental Units

TCL	Chlorite-altered tuff/brecciated diorite/andesitic lapilli tuff - black to dark grey weathering with rusty iron carbonate blebs and veinlets throughout. Rare light coloured, sub-angular fragments occur in a fine-grained dark grey matrix.
THLA	Heterolithic lapilli tuff with argillite clasts - This lithology is generally flaggy and weathers light pink-brown with silvery coloured fragments and weathered-out iron carbonate blebs. The fragments are dominantly pale green volcanic rock and lesser, but distinct, fine-grained black argillite fragments that average 0.5 to 1.0 cm across. Locally this unit is very coarse-grained with argillite clasts up to 50 cm across.
THL	Heterolithic lapilli tuff - this unit is similar to THLA but has no argillite clasts
CO3	Narrow white limestone bands and lenses within the volcanic package.
THLAB	THLA interbedded with narrow bands of black argillite.
THLMG	Maroon and green heterolithic lapilli tuff - In general this unit has a maroon matrix with dominantly pale green and lesser pale grey clasts that average 1 to 3 cm across. Locally this unit is very coarse grained with trachyte fragments up to 60 cm across (locally may include narrow bands and lenses of argillite).
TLP	Pyritic/sulphidized lapilli tuff - weathers rusty yellow and gossanous to bleached. Pyritic clasts generally less than 1 cm across occur in a light grey matrix.
TQX	Quartz (feldspar) crystal tuff - weathers medium grey with cream and black fragments. Fresh surfaces are medium grey with trace to 5% glassy quartz crystals 1 to 3 mm in diameter.
TLBP	Brown-pink lapilli tuff - Flaggy, light pinkish brown weathering tuff with rounded, fine-grained, pale grey to pale green, rarely feldspar phyric, fragments (trachyte?) 2 to 15 mm across.
AHB	Heterolithic felsic agglomerate/breccia - Weathers light grey with rusty blebs. Angular, fine-grained, grey fragments up to 30 cm across occur in a medium to dark grey matrix.
SyBx	Syenite breccia - weathers light grey to white, monolithic with fine-grained angular fragments from 1 to 15 cm across. Locally the fragments include white feldspar and rounded quartz crystals.
Arg	Argillite - black to silvery grey, fissile, locally laminated, rarely finely striped grey and green.
SFC	Interbedded sandstone, shale/argillite and iron carbonate cemented breccia
Su	Undivided sedimentary rocks - made up of interbedded argillite and fine- to coarse-grained buff coloured sandstone.
Und_1	Undivided unit made up of Tr, THLA and THLMG
Und_2	Undivided unit made up of THLA and THLMG
[illegible]	Gossan

"DEVONO-MISSISSIPPIAN" or "DEVONIAN or older"

Und_3	Undivided unit made up of grit, conglomerate and THLA. It is not clear if this unit is part of the Devono-Mississippian volcanic sequence or the overthrust package.

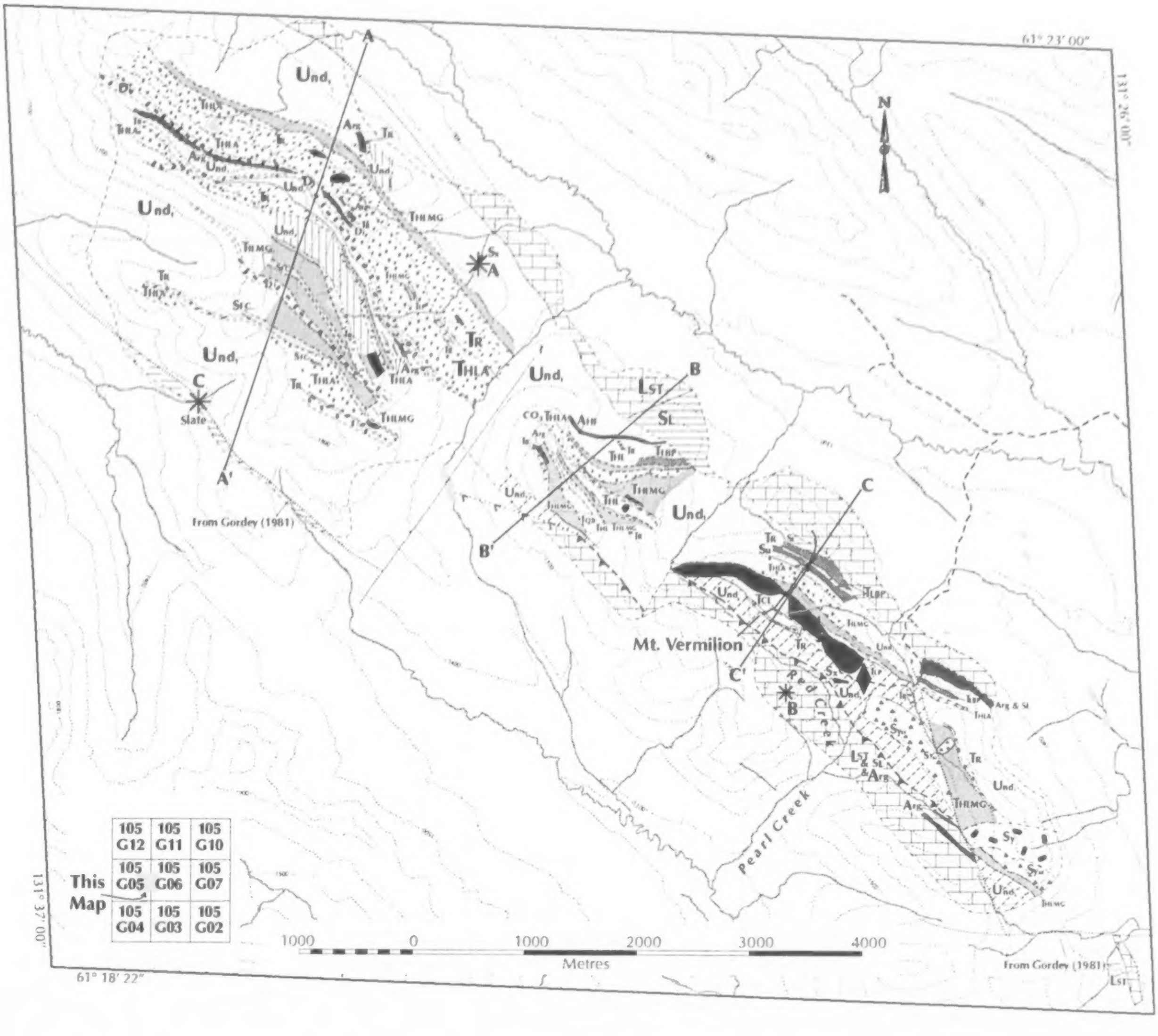
DEVONIAN or older

LST	Limestone/dolomite - cliff forming carbonate weathers light grey to brown, is massive to well bedded, locally brecciated, locally crinoidal and locally fine-grained and laminated.
SL	Limey siltstone/shale
S	Carbonate, sandstone, grit and argillite - brown to grey to cream weathering, massive, grey, locally fossiliferous and/or bioturbated carbonate with minor sandstone interbeds; dark brown weathering coarse-grained sandstone; polymictic grit made up of varicoloured fine-grained cherty clasts in an argillaceous matrix; black, fissile argillite.
Slate	Grey weathering lustrous tuffaceous slate; minor orange or grey weathering sandstone.

Figure 3. *(continued) Cross sections and legend for Figure 3.*

GEOLOGY

In the Mount Vermilion area, at the southeast end of the belt, the volcanic succession is made up primarily of felsic volcaniclastic material with lesser sills/dykes/flows and minor intermediate sills/dykes/flows. At the northwest end of the belt volcanic units of intermediate composition constitute the bulk of the volcanic succession, however, felsic volcanics occur midway through the volcanic sequence. Within these felsic volcanic rocks, Morin (1977) and Mortensen (1979) described several submarine volcanic complexes where extensive volcaniclastic strata are interbedded with flows and tuffaceous chert, and intruded by felsic domes and stocks. These syenitic intrusions were considered by Tempelman-Kluit (1976), Morin (1977) and Mortensen (1979, 1981) to be the subvolcanic equivalent of some of the felsic tuffs and flows. Locally, the felsic tuffs contain pyrite and are immediately overlain by massive sulphide lenses (Morin, 1977; Mortensen, 1979, 1981). Pervasive clay and carbonate alteration characterize the felsic volcanic unit.


61° 23' 00"
131° 26' 00"
N
A
Und.
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Und.
Und.
THLA
THMG
TR
ARG
Slate
C
A'
From Gordey (1981)
B
LST
SL
CO, THLA
THMG
Und.
B'
C
Mt. Vermilion
C'
B
Pearl Creek
LST & SL & ARG
Arg & Sl
Und.
THMG
SY
105 G12
105 G11
105 G10
105 G05
105 G06
105 G07
105 G04
105 G03
105 G02
This Map
131° 37' 00"
61° 18' 22"
1000
0
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2000
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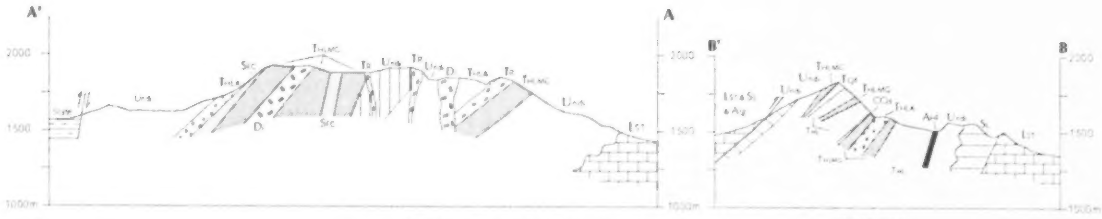
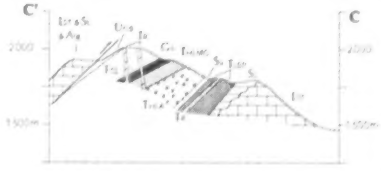
Metres
From Gordey (1981)
LST

Figure 3. Bedrock geology sketch map of the Mount Vermilion area, Pelly Mountains with some geological contacts taken from Gordey (1981).





MINERAL OCCURRENCES			
Yukon Minfile Number	Name	Deposit	Type
116C 008	Wolf	♦	VMS
Previously unreported mineral occurrences			
	A	✳	
	B	✳	
	C	✳	

SYMBOLS

Limit of mapping

Geological contact (defined, approximate, assumed and/or covered)

Fault (defined, approximate, assumed and/or covered)

Thrust fault (defined, approximate, assumed and/or covered)

Bedding — 24 — VERTICAL

Foliation — 67 — VERTICAL

Cross-section line — A — A'

Stratigraphic section location

Winter trail

LEGEND

DEVONO-MISSISSIPPIAN

Non-fragmental Units

Sy	Syenite – grey weathering, grey to white or rarely pink, very fine-grained to pegmatitic with pink feldspar crystals up to 4 cm long. Disseminations and blebs of pyrite occur throughout the intrusion with rare fluorite.
TR	Trachyte flows, sills and dykes – dark rusty brown to yellow or grey weathering, fresh surfaces are dark pinkish brown to light grey with numerous iron carbonate filled vesicles. Locally fine-grained glassy needle-like feldspar crystals are visible.
Di	Diorite/andesite flows, sills and dykes – medium grey-green to brown weathering with a pitted surface. Fresh surfaces are medium green with relict biotite? and feldspar crystals and trace fine-grained disseminated pyrite. Locally the rocks is cut by numerous carbonate filled fractures.

Fragmental Units

TCL	Chlorite-altered tuff/brecciated diorite/andesitic lapilli tuff – black to dark grey weathering with rusty iron carbonate blebs and veinlets throughout. Rare light coloured, subangular fragments occur in a fine-grained dark grey matrix.
THLA	Heterolithic lapilli tuff with argillite clasts – This lithology is generally flaggy and weathers light pink-brown with silvery coloured fragments and weathered-out iron carbonate blebs. The fragments are dominantly pale green volcanic rock and lesser, but distinct, fine-grained black argillite fragments that average 0.5 to 1.0 cm across. Locally this unit is very coarse-grained with argillite clasts up to 50 cm across.
THL	Heterolithic lapilli tuff – this unit is similar to THLA but has no argillite clasts
CO3	Narrow white limestone bands and lenses within the volcanic package.
THLAB	THLA interbedded with narrow bands of black argillite.
THLMG	Maroon and green heterolithic lapilli tuff – In general this unit has a maroon matrix with dominantly pale green and lesser pale grey clasts that average 1 to 3 cm across. Locally this unit is very coarse grained with trachyte fragments up to 60 cm across (locally may include narrow bands and lenses of argillite).
TLP	Pyritic/sulphidized lapilli tuff – weathers rusty yellow and gossanous to bleached. Pyritic clasts generally less than 1 cm across occur in a light grey matrix.
TQX	Quartz (feldspar) crystal tuff – weathers medium grey with cream and black fragments. Fresh surfaces are medium grey with trace to 5% glassy quartz crystals 1 to 3 mm in diameter.
TLBP	Brown-pink lapilli tuff – Flaggy, light pinkish brown weathering tuff with rounded, fine-grained, pale grey to pale green, rarely feldspar phyric, fragments (trachyte?) 2 to 15 mm across.
AHF	Heterolithic felsic agglomerate/breccia – Weathers light grey with rusty blebs. Angular, fine-grained, grey fragments up to 30 cm across occur in a medium to dark grey matrix.
SyBx	Syenite breccia – weathers light grey to white, monolithic with fine-grained angular fragments from 1 to 15 cm across. Locally the fragments include white feldspar and rounded quartz crystals.
Arg	Argillite - black to silvery grey, fissile, locally laminated, rarely finely striped grey and green.
SFC	Interbedded sandstone, shale/argillite and iron carbonate cemented breccia
Su	Undivided sedimentary rocks - made up of interbedded argillite and fine- to coarse-grained buff coloured sandstone.
Und1	Undivided unit made up of Tr, THLA and THLMG
Und2	Undivided unit made up of THLA and THLMG
Go	Gossan

"DEVONO-MISSISSIPPIAN" or "DEVONIAN or older"

Und	Undivided unit made up of grit, conglomerate and THLA. It is not clear if this unit is part of the Devono-Mississippian volcanic sequence or the overthrust package.

DEVONIAN or older

LST	Limestone/dolomite – cliff forming carbonate weathers light grey to brown, is massive to well bedded, locally brecciated, locally crinoidal and locally fine-grained and laminated.
SL	Limey siltstone/shale
S	Carbonate, sandstone, grit and argillite – brown to grey to cream weathering, massive, grey, locally fossiliferous and/or bioturbated carbonate with minor sandstone interbeds; dark brown weathering coarse-grained sandstone; polymictic grit made up of varicoloured fine-grained cherty clasts in an argillaceous matrix; black, fissile argillite.
Slate	Grey weathering lustrous tuffaceous slate; minor orange or grey weathering sandstone.

Figure 3. *(continued) Cross sections and legend for Figure 3.*

STRUCTURE

The Pelly-Cassiar Platform, including the Pelly Mountains volcanic belt, is internally repeated by folds and northeast-directed thrust faults which involve strata as young as Upper Triassic (Tempelman-Kluit, 1977a). The northwestern end of the volcanic belt has been affected by three phases of deformation (Mortensen, 1981). All three phases are seen together only near the MM occurrence (Fig. 2); in other parts of the belt the folding is less intense. The first two phases are coaxial with a general northwesterly trend; the third phase produced northeasterly trending regional warps (Mortensen, 1979; 1981). Mortensen (1981) suggested the first two phases of deformation reflect nappe development during thrusting, and the unrelated third phase is possibly the result of intrusion of Cretaceous granitic batholiths to the southwest, or initial wrenching on the Tintina Fault. The southeast end of the belt is less deformed than the northwest end and folds are rarely seen. Gordey (1977) shows that the Mount Vermilion area is essentially homoclinal with moderate dips to the south. Near Mount Vermilion, dolomite overlies the volcanic succession along a moderately to steeply southwest-dipping fault, the Vermilion thrust (Fig. 3; Gordey, 1977, 1981). This fault has an estimated stratigraphic separation of about 1800 m and minimum overlap of about 3.5 km (Gordey, 1977).

METAMORPHISM

Most of the volcanic strata are lower greenschist facies regional metamorphic grade (Gordey, 1981; Tempelman-Kluit et al., 1976); the southern part of the northwest end of the belt, around the MM occurrence, has undergone a higher degree of metamorphism. There the strata reach lower amphibolite facies (Mortensen and Godwin, 1982).

AGE

Based on the following comparisons with the northwest end of the belt and similar strata in the Selwyn Basin, the volcanic rocks in the Mount Vermilion area are considered to be Late Devonian to Early Mississippian (Gordey, 1977).

- Rare conodonts and brachiopods from the upper part of the shale unit which underlies, overlies, and is laterally equivalent to the volcanic succession in the northwest end of the belt (Mortensen, 1979 and 1981) were tentatively identified as mid-Mississippian (Visean; B.E.B. Cameron and E.W. Bamber, pers. comm., quoted in Tempelman-Kluit et al., 1976; Gordey, 1977). The volcanic rocks at the southeast end of the belt unconformably (?) overlie the Middle (?) Devonian dolomite and are intercalated with shale which resembles the Late Devonian to Early Mississippian Earn Group (Gordey, 1977).
- A Rb-Sr age date of 333.0 ± 10.0 Ma for the Pelly Mountains volcanism was obtained by Chronic (1979) from a skarn developed adjacent to a large syenite stock. This syenite may have fed the felsic tuffs near the middle of the volcanic pile; thus the volcanism is considered to be Middle Mississippian in age (Chronic, 1979; Mortensen, 1981; Mortensen and Godwin, 1982).
- Sedimentary strata in the volcanic belt include some with lithological similarities to Upper Devonian and Mississippian shales of the Selwyn Basin (Blusson, 1976; Gordey, 1978, 1979).

GEOCHEMISTRY

A plot of Nb/Y versus Zr/TiO_2 by Mortensen (1981) for rocks from the northwest end of the belt shows them to be trachytes. Analysis of ten unweathered specimens from the southeast end of the belt by Gordey (1977) shows they have a chemical composition intermediate between calc-alkali trachytes and calc-alkali rhyolites.

Geochemical data reported by Morin (1977), Gordey (1977), Chronic (1979) and Mortensen (1981) show that the volcanic rocks represent a highly metaluminous and peralkaline suite likely generated in an extensional regime. Contemporaneous extension has been documented within the Selwyn Basin and the unconformity which occurs beneath the volcanic sequence suggests at least local uplift (Blusson, 1976; Tempelman-Kluit and Blusson, 1977; Gordey, 1978, 1979).

Chronic (1979) described a poorly defined but high initial $^{87}Sr/^{86}Sr$ (0.7099 ± 12) for syenite suggesting the source of the syenite melt was crustal.

GEOLOGY OF THE MOUNT VERMILION AREA

The southeast end of the volcanic belt was mapped at a scale of 1: 25 000 (Fig. 3) and several sections across the stratigraphy were measured (Fig. 4 and Appendix 1). Although no marker horizons were recognized, general transitions may be followed. In the Mount Vermilion area, the Devono-Mississippian volcanic belt contains non-fragmental, fragmental, epiclastic and other rocks, all of which are described below along with brief summaries of over- and underlying rocks and previously unreported mineralization.

UNDERLYING ROCKS

In the Mount Vermilion area, the volcanic package unconformably overlies cliff-forming carbonate and limey siltstone/shale (Gordey and Tempelman-Kluit, 1976; Gordey, 1977). In the section measured on Mount Vermilion (Fig. 4 and Appendix 1), this contact is an angular unconformity where moderately east-dipping carbonate beds are overlain by the moderately south-dipping volcanic succession. The cliff-forming carbonate weathers light grey to brown and is massive to well bedded. It is also locally brecciated, especially near the contact with the overlying volcanic succession. Breccia fragments range from less than 1 to 3 cm across in a dark grey sandy to cherty matrix. The carbonate contains rare crinoid debris; locally, it is fine-grained and laminated.

The age of this carbonate unit is based on fossil collections from similar strata in the Pelly Mountains that range from probable mid-Silurian to Middle Devonian age (D.J. Tempelman-Kluit, pers. comm. in Gordey, 1981).

Near the base of the measured section on Mount Vermilion, a 1-m wide diorite dyke cuts the brecciated carbonate and is paralleled by a 0.3 m thick highly fractured, rusty weathering white quartz vein. There is also rare float of dark rusty weathering oxidized highly porous rock (remnant massive sulphide?) nearby.

DEVONO-MISSISSIPPIAN VOLCANIC BELT

NON-FRAGMENTAL

• *SYENITE - INTRUSION (SY)*

Rubbly weathering, fine to very coarse-grained syenite was seen only on the ridge crest immediately east of the Wolf deposit (Figs. 3 and 5) where it is partly buried by talus. However, drill hole and geophysical information suggests that it underlies a large part of the ridge and may form a thick sill-like body.

The border of the intrusion is very fine-grained and grey but becomes medium-grained within several metres of the contact with white feldspar crystals in a chloritized groundmass. Locally the intrusion is pegmatitic with dark pink potassium feldspar crystals up to 4 cm long. There are disseminations and blebs of pyrite throughout the intrusion and very rare fluorite.

This syenite is similar to those described by Morin (1977) and Mortensen (1979) for the northwest end of the belt where they are interpreted to represent former volcanic centres. Chronic (1979) describes melagranite and mafic dykes that are cogenetic with nearby Mississippian syenite at the northwestern end of the volcanic belt in the Guano area. In the Mount Vermilion area the syenite was not seen to be gradational with the trachyte flows and no proximal dykes or sills were found. However, no other possible source for the trachyte flows/dykes/sills has been found to date.

• *MONZONITE/TRACHYTE - FLOWS, SILLS, DYKES (TR)*

Dark generally rusty brown weathering monzonite/trachyte occurs throughout the area. Unweathered surfaces are dark pinkish brown with numerous iron carbonate-filled vesicles about 4 mm in diameter, to medium grey with white to cream

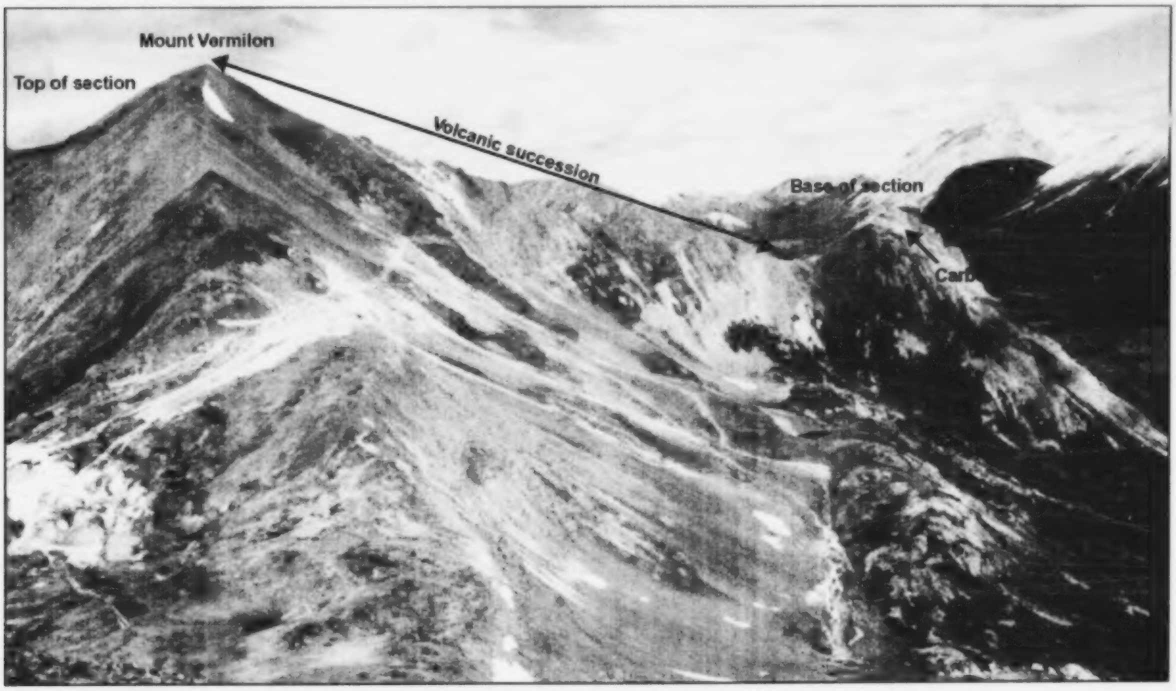


Figure 4. *View of the Mount Vermilion stratigraphic section, looking to the northwest.*

blebs (feldspar?; Fig. 6a). Locally the rocks contain 1 to 5% fine-grained disseminated pyrite blebs. Locally, this unit is siliceous and hard, especially at fine-grained margins (chilled?) which may be up to 5 m thick and commonly have numerous iron carbonate blebs, possibly the remnants of peperitic texture (Fig. 6b).

The trachyte locally weathers yellow to dark orange to dark hematitic maroon to brown; the contacts of this unit may weather bright rusty orange with iron carbonate blebs and veinlets. Fresh surfaces are locally light grey with about 1% fine-grained disseminated pyrite throughout. Locally fine-grained, glassy feldspar needles are visible throughout the rock (Fig. 6c). Very rarely quartz phenocrysts 1 to 2 mm in diameter occur within this unit. Locally, the surface of the trachyte is frothy suggesting it is a flow rather than a dyke/sill. Lower sill/dyke contacts are generally parallel to bedding, but upper contacts typically crosscut bedding.

In the lower part of the section, the trachyte is similar in appearance to the brown-pink lapilli tuff (Tlpb, see later) minus the fragments. This trachyte is amygdaloidal and vesicular with some quartz, and numerous iron carbonate-filled vesicles.

The description of trachyte flows by Morin (1977) from the northwest end of the belt matches that for the Mount Vermilion area, especially the presence of orange-brown siderite amygdules.

• *DIORITE/ANDESITE - FLOWS, SILLS/DYKES (DI)*

This unit occurs near the top of the volcanic section where it forms resistant bands that can be traced from ridge to ridge. The intermediate rocks weather medium grey-green with black specks (chloritized mafics ?), to brown with a pitted (vesicular-looking) surface (Fig. 7 a & b); fresh surfaces are medium green with black relict biotite (?), relict feldspar that is locally needle-like, and trace fine-grained disseminated pyrite blebs. The rock is hard and dense, and locally very fine-grained near the margins.

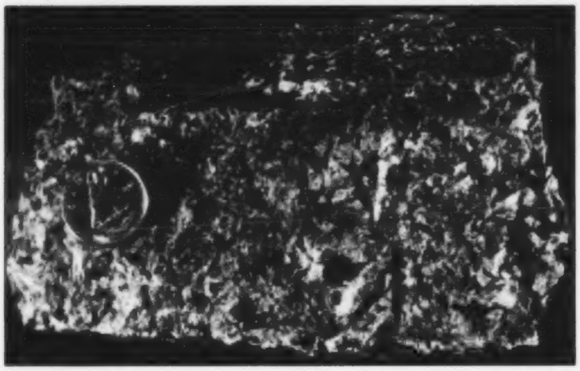


Figure 5. *(Sy) Coarse-grained syenite.*

In places the rock is strongly fractured with fractures/tension gashes filled by carbonate.

Near the base of the measured section on Mount Vermilion a 1 m wide diorite dyke cuts the underlying brecciated carbonate. The dyke is massive, fine-grained and weathers dark grey with rusty to buff coloured feldspar crystals. The weathered surface of the dyke is pitted and locally finely laminated flow banding is visible. It is not clear if this dyke is related to the intermediate flows/sills/dykes which occur in the Devono-Mississippian volcanic package or if it is part of a younger intrusive event.

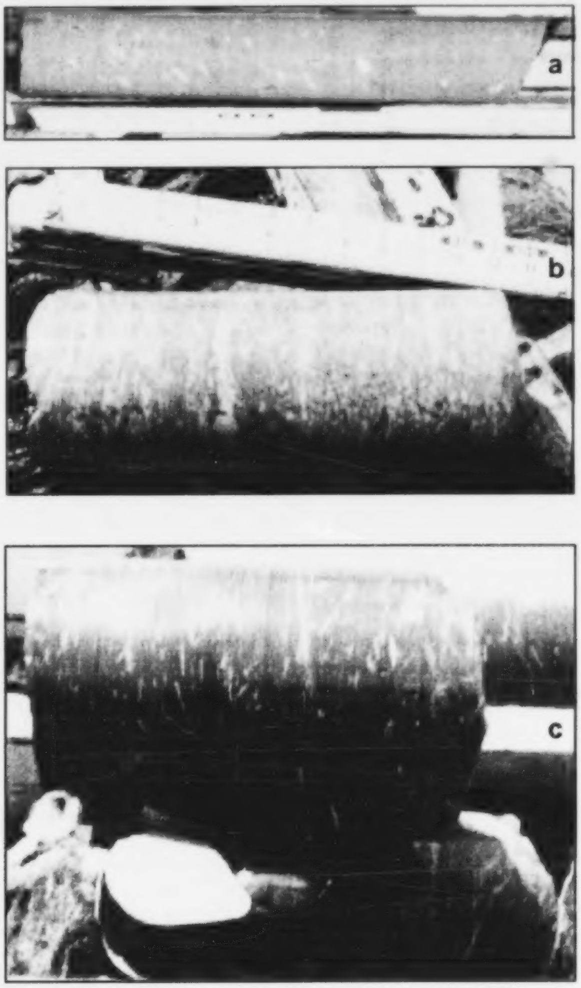


Figure 6. *(Tr)* ***a)*** *amygdaloidal trachyte;* ***b)*** *possible peperitic texture at the border of a trachyte sill;* ***c)*** *acicular feldspar crystals in trachyte. All drill core is from the Wolf property.*

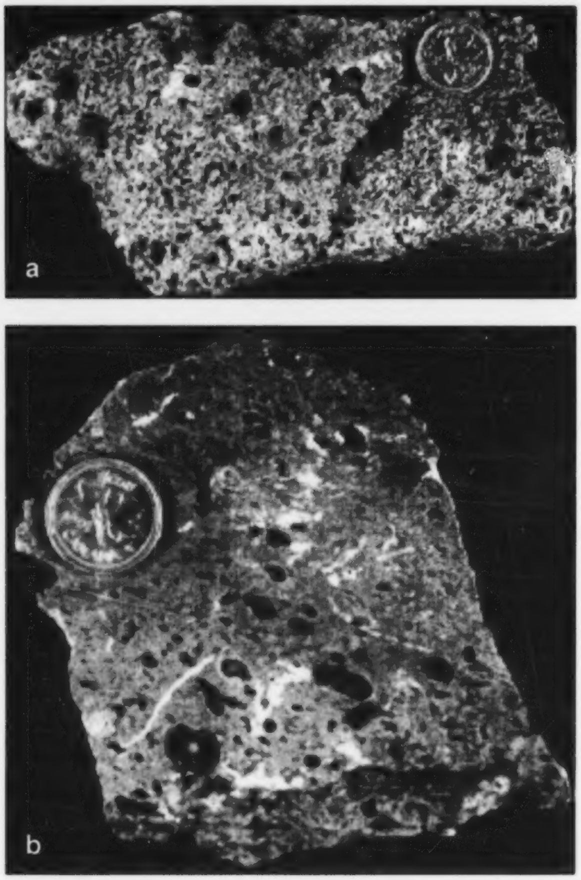


Figure 7. *(Di) Coarse- and fine-grained intermediate sills with a vuggy texture caused by the dissolution of iron carbonate blebs;* ***a)*** *coarse-grained,* ***b)*** *fine-grained.*

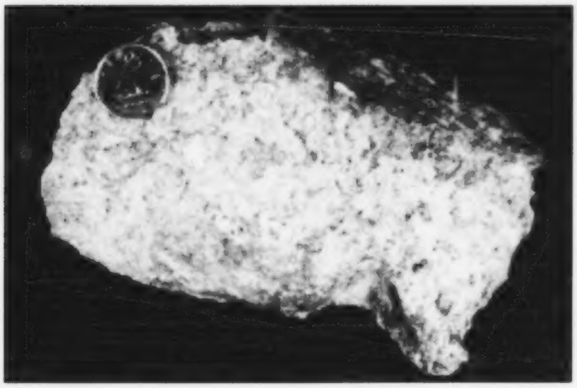


Figure 8. *(Tlbp) Pink-brown weathering lapilli tuff.*

FRAGMENTAL

- ***PINK-BROWN LAPILLI TUFF (TLPB)***

Pink-brown lapilli tuff near the base of the stratigraphic section measured on Mount Vermilion is light pinkish brown weathering and flaggy (Fig. 8). It is interlayered with trachyte flows, sills and narrow (1 m or less) argillite beds. Fragments within the tuff are dominantly rounded, fine-grained, pale grey to pale green (altered to sericite?), ranging from 2 to 15 mm in diameter. Locally, the fragments are concentrated in layers about 3 cm thick. Rare unaltered fragments are fine-grained and grey with white feldspar phenocrysts about 1 mm long (trachyte?). Very rare fine-grained black fragments, possibly argillite, also occur in this unit. Locally, the tuff is compositionally banded with waxy, green, fine laminations. The tuff matrix is fine-grained, contains 1 to 5% fine-grained disseminated pyrite and is locally hematitic. Iron carbonate blebs and veinlets occur locally within the tuff, as do minor quartz veinlets containing traces of galena.

- ***HETEROLITHIC LAPILLI TUFF WITH ARGILLITE CLASTS (THLA, THL, THLAB)***

This unit is generally flaggy and weathers light pink-brown with silvery coloured fragments and weathered out iron carbonate blebs throughout. This rock type is distributed throughout the map area and occurs at various stratigraphic levels. However, in general, it occurs above Tlpb and below or interbedded with maroon and green lapilli tuff (see below). Within the heterolithic lapilli tuff unit the fragments are dominantly green (sericitized?) volcanic rock with lesser, but distinct, fine-grained black argillite clasts which range from 0.5 to 3 cm and average 0.5 to 1.0 cm Fig. 9). Viewed altogether, the unit varies between very coarse-grained and very fine-grained end members.

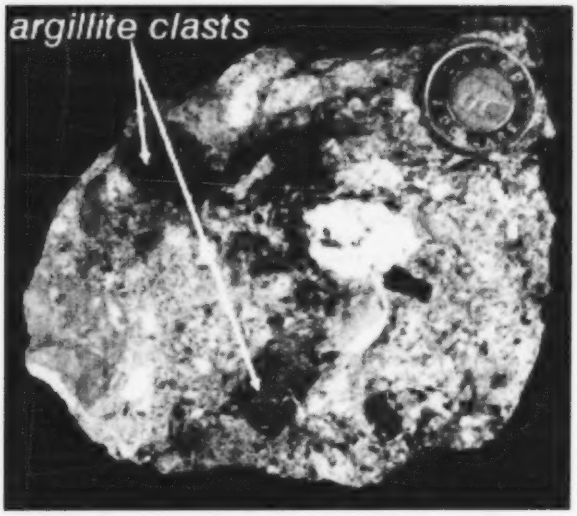


Figure 9. *(Thla) Heterolithic lapilli tuff with distinct argillite clasts.*

The very coarse-grained variety contains angular to sub-rounded argillite clasts up to 50 cm across which rarely show normally graded bedding. It is locally interbedded with medium-grained tuff beds about 20 cm thick. Rarely the coarse-grained end member is poorly foliated with blocky fractures.

The very fine-grained end member is dark grey, revealing beige flattened ellipses on the weathered surface 0.5 to 2 cm long. This fine-grained unit is locally hematitic and has minor argillite clasts 0.2 to 3 cm across and rare rectangular, sericitized finely laminated clasts.

Lithologically related to unit Thla are two sub-units, Thl and Thlab. Thl has no argillite clasts and Thlab is made up of Thla interbedded with narrow bands of black argillite.

- ***MAROON AND GREEN LAPILLI TUFF (NO ARGILLITE CLASTS; THLMG)***

In general this rock unit has a distinctive maroon matrix that hosts green fragments (Fig. 10). This rock type occurs throughout the map area and commonly overlies or is interbedded with unit Thla. In the measured section on Mount Vermilion, fine-grained, rubbly, maroon tuff occurs at the top of this unit and underlies rusty and bleached rocks that likely represent the surface expression of the mineralization at the Wolf deposit. About 50 m east of the Mount Vermilion section, immediately underlying pyritic lapilli tuff (Tlp), the matrix is locally green and the fragments are hematitic maroon.

Within this unit, rounded to subangular fragments are dominantly pale green, or less commonly pale grey. Clasts average 1 to 3 cm across and are generally hosted in a fine-grained maroon matrix. Locally, this unit is intensely foliated, fine-grained and pale green (looks like sericite schist) or maroon; fissility increases as the fragment size decreases.

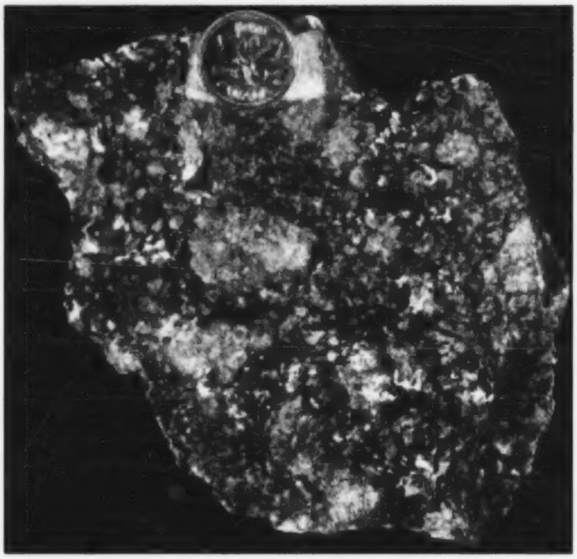


Figure 10. *(Thlmg) Maroon matrix tuff with green lapilli-sized fragments.*

In the centre of the horseshoe-shaped ridge 2 km west of Mount Vermilion, the maroon and green lapilli tuff is very coarse-grained with rounded frothy/vesicular light green trachyte fragments 5 to 60 cm across that average 10 cm, in a maroon matrix. This coarse-grained unit is monolithic, containing only trachyte fragments. The matrix is also fragmental, containing tiny grey cherty fragments as a minor component. In this location, Thlmg is interbedded with Thla which is also very coarse-grained. Together these two units form a section about 100 m thick with a limited lateral extent. This area may represent a site closer to a vent source or coarse-grained debris close to a fault scarp.

- ***HETEROLITHIC FELSIC AGGLOMERATE/BRECCIA (AHF)***

These light grey weathering rocks were seen only at the base of the section made up of very coarse-grained Thlmg and Thla (see above). The agglomerate/breccia is made up of fragments which range from 5 to 30 cm and average about 10 cm across, in a medium to dark grey matrix. The matrix contains rare white crystals and grey cherty angular fragments less than 0.5 cm in diameter. The rock contains about 4% fine-grained, grey angular fragments, 30% grey, laminated angular fragments with black specks (mafics ?) and 1% rounded, foliated cream to grey fragments. The unit contains rusty blebs and minor iron carbonate alteration and is locally cut by a narrow fine-grained, grey siliceous dyke.

- ***PYRITIC/SULPHIDIZED LAPILLI TUFF (TLP)***

This unit is recognizable in drill core but is rarely visible in outcrop because it weathers recessively to rusty yellow, bleached and gossanous material. This unit can occur stratigraphically above and/or below the mineralization (Holbek and Wilson, 1998; Atna personnel, pers. comm., 1998). In drill core, it contains pyrite clasts generally less than 1 cm across within a light grey matrix.

- ***QUARTZ (FELDSPAR) CRYSTAL TUFF (TQX)***

This unit is rare and generally occurs close to the top of the section, above Thlmg. It weathers medium grey with cream-coloured fragments 0.5 to 2 cm across that are visible only on the weathered surface, and black fragments less than 0.5 cm across. Fresh surfaces are medium grey and siliceous with up to 5% glassy quartz crystals 1 to 3 mm in diameter. The unit has iron carbonate alteration and blocky fractures.

- ***CHLORITE-ALTERED TUFF/BRECCIATED DIORITE/ANDESITIC LAPILLI TUFF (TCL)***

This unit occurs near the top of the Mount Vermilion section, above the mineralized horizon. The unit is black to dark grey

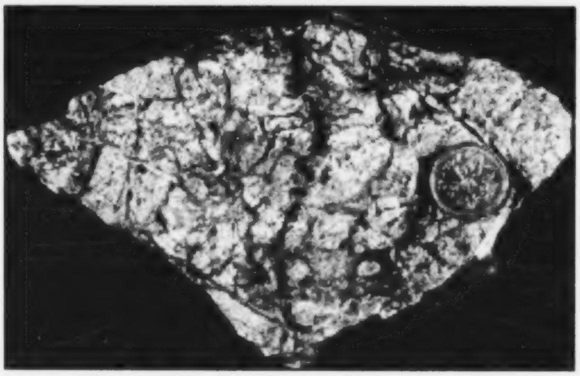


Figure 11. *(Sybx) Syenite fragments in a fine-grained matrix.*

weathering with rusty iron carbonate blebs and veinlets throughout. Rare light coloured, sub-angular fragments about 1 cm across are distributed in a fine-grained dark grey matrix. Although the base of this unit is strongly fractured and rubbly, there is an upward increase in competency, a change in colour to medium grey with a pitted brown weathered surface; iron carbonate blebs and small argillite clasts become more numerous and rare white amygdules are present. This fragmental unit is unique in that it has chlorite alteration.

- ***SYENITE BRECCIA (SYBX)***

Immediately east and south of the syenite intrusion is a monolithic breccia that weathers light grey to white with fine-grained angular fragments from 1 to 15 cm across (Fig. 11). Among the fragments are white feldspar crystals 1 cm long and rounded quartz crystals 1 cm in diameter. The matrix is fine-grained and light to dark grey and generally crowded with randomly oriented fragments. Locally, this unit has been silicified and/or has chlorite alteration.

This unit may be a tectonic breccia as it is near the contact with overlying carbonate and shale that is interpreted as a thrust. Alternatively it could represent the "explosive intrusion" of the syenite emplaced at shallow depths.

EPICLASTIC

- ***ARGILLITE (ARG, SU)***

Bedded, locally lensoid, argillite (Arg) occurs throughout the volcanic succession but is most abundant near the base where it is up to 14 m thick. The lenses decrease in thickness and number upsection. The argillite is black to silvery grey, generally fissile, and locally finely laminated. Rarely it is finely striped grey and green. Locally argillite is cut by trachyte sills/dykes, especially at the base of the Mount Vermilion section, suggestive of a sediment-sill complex. Near the top of the succession, dykes/sills of intermediate composition contain large argillite lenses.

Unit Su consists of interbedded argillite and fine to coarse-grained, buff coloured sandstone.

- ***INTERBEDDED SANDSTONE AND SHALE/ARGILLITE/IRON CARBONATE CEMENTED LAPILLI TUFF/BRECCIA (SFC)***

This unit weathers a distinctive bright rusty orange due to breccia bands about 20 cm thick that have sandstone fragments about 10 cm across in an iron carbonate matrix. In general this unit is weakly foliated (some clasts appear flattened) and varies from very coarse-grained to fine-grained. The shale/argillite component is black and silky with beds 5 to 10 cm thick. The sandstone is dominantly coarse-grained and poorly sorted with minor fine-grained black (argillite?) and light grey cherty clasts up to 1 cm across. Fine-grained sandstone, a minor constituent, has rare cross-bedding. Grading within the sandstone beds indicates they are the right-way-up.

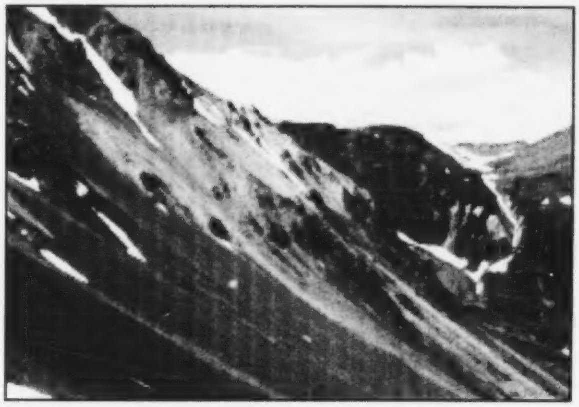


Figure 12. *Gossan horizon on Mount Vermilion that likely represents the surface expression of the main mineralized horizon at the Wolf deposit.*

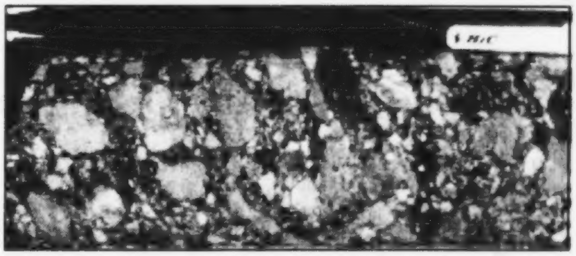


Figure 13. *Polymictic grit made up of vari-coloured cherty fragments in an argillaceous matrix.*

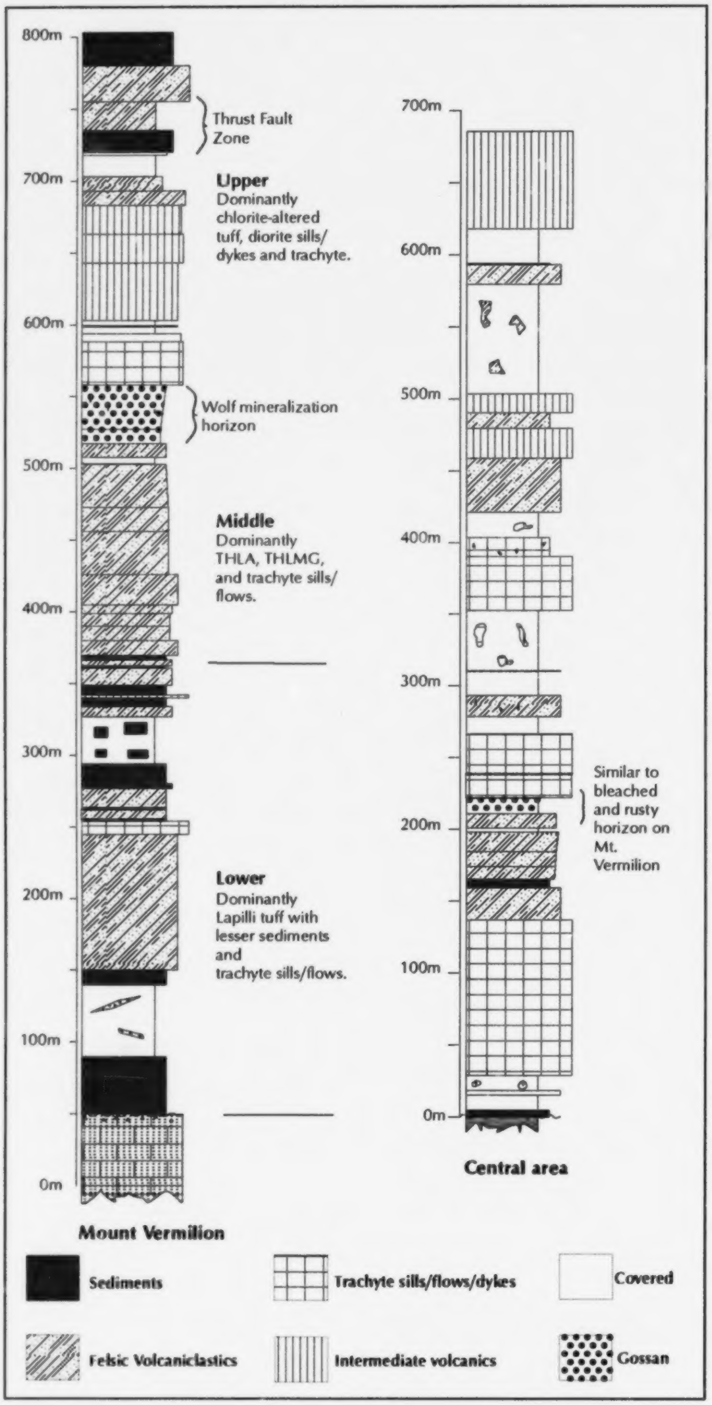

800m
700m
600m
500m
400m
300m
200m
100m
0m
Thrust Fault Zone
Upper
Dominantly chlorite-altered tuff, diorite sills/ dykes and trachyte.
Wolf mineralization horizon
Middle
Dominantly THLA, THLMG, and trachyte sills/ flows.
Lower
Dominantly Lapilli tuff with lesser sediments and trachyte sills/flows.
Mount Vermilion
700m
600m
500m
400m
300m
200m
100m
0m
Similar to bleached and rusty horizon on Mt. Vermilion
Central area
Sediments
Trachyte sills/flows/dykes
Covered
Felsic Volcaniclastics
Intermediate volcanics
Gossan

Figure 14. *Simplified stratigraphic sections for the southeast and central areas of the Pelly Mountains volcanic belt. For more detailed sections see Appendix 1.*

OTHER

- ***GOSSAN/SULPHIDE HORIZON AT SURFACE (SULPHIDES AND TRACHYTE BRECCIA?)***

In the Mount Vermilion section, the approximate level of the Wolf sulphide horizon has decomposed to white quartz ± barite that is bleached and weathers rusty yellow (Fig. 12). Within this gossanous "horizon" are fine-grained, bleached, locally baritic rocks, and white fine-grained rock with rare cream-coloured blebs (fragments?) that is pitted (weathered out sulphides?). Upsection, fine-grained fragments are easier to see on the weathered surface where they vary from grey with white amygdules (trachyte?), to cream-coloured to grey. Locally the rock is siliceous and in some places has a frothy texture. Rare fresh rock is medium grey and glassy, with no visible fragments.

OVERLYING ROCKS

SANDSTONE, GRIT, ARGILLITE, LIMESTONE/ DOLOMITE (OCS, UND$_3$)

In the Mount Vermilion area the volcanic succession is topographically overlain by coarse-grained sandstone and grit, argillite, and massive rusty weathering carbonate. These rocks were interpreted by Tempelman-Kluit et al. (1976) and Gordey (1977, 1982) as Ordovician Road River and ?Earn Group-equivalent strata that had been thrust over the volcanic package, however, this contact is not directly exposed and at least locally, the bedding is roughly parallel above and below the contact.

Immediately south and east of Mount Vermilion, close to the mapped contact, is a unit of interlayered coarse-grained sandstone, polymictic grit and argillite (Und$_3$) which may include some Thla. It is not clear if this unit is part of the volcanic succession or the overlying carbonate and argillite package. The coarse-grained sandstone is locally siliceous and weathers dark brown. Polymictic grit is made up of vari-coloured fine-grained cherty clasts in an argillaceous matrix (Fig. 13). Massive grey carbonate with minor sandstone interbeds weathers brown, grey and cream-coloured, and is locally fossiliferous and bioturbated. Most of the overlying rocks are iron carbonate altered, especially near the thrust contact. Within these sedimentary rocks are rare patches of porous rusty "fericrete-like" rubble that may be the remnants of massive sulphide mineralization.

The massive carbonate is similar to that which underlies the volcanic succession. In general it is resistant and weathers rusty brown to light grey with a nodular surface. The carbonate is thick bedded and is exposed on the ridges immediately south of the thrust fault (Fig. 3).

DISCUSSION – MOUNT VERMILION AREA

Within the map area no marker units were identified and no single unit could be traced for more than a few hundred metres, with the exception of trachyte and intermediate sills/dykes. This may be due to rapid facies changes and/or faulting. For example, about 1 km west of Mount Vermilion, very coarse-grained fragmental volcanic strata (Thla, Thlmg, Ahf), approximately 100 m thick, occur over a lateral distance of only a few tens of metres. This area likely represents a site closer to a vent source or a fault scarp.

Three stratigraphic sections were measured across the volcanic belt and the following transitions were observed (Fig. 14 and Appendix 1).

At the southeast end of the belt, the volcanic succession has a lower part that consists of interbedded volcaniclastic rocks and argillite with minor trachyte sills/dykes, a middle section of volcaniclastic rocks and trachyte flows/sills/dykes, and an upper chlorite-altered part containing intermediate dykes and flows.

To the west, towards the centre of the volcanic belt the volcaniclastic component decreases as the number of sills, flows and dykes becomes more numerous, and the amount of intermediate volcanic material increases.

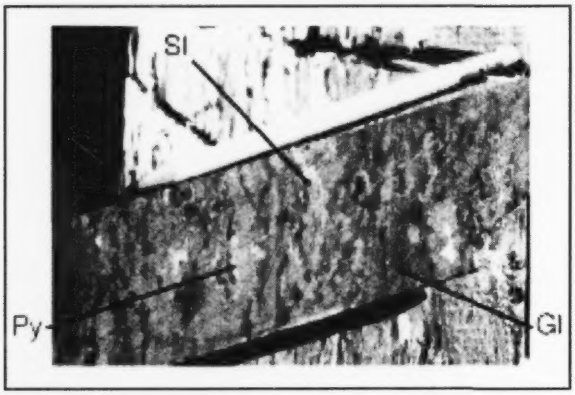


Figure 15. *Pyrite (Py)-sphalerite (Sl)-galena (Gl) mineralization from the Wolf deposit.*

At the northwest end of the belt, Mortensen (1979) described a volcanic succession of intermediate composition with felsic, dominantly volcaniclastic rocks near the middle. This succession does not resemble that in the southeast end of the belt, where the volcanic succession is primarily felsic with some intermediate flows, sills and dykes in the upper part. However, the middle felsic portion is similar to the felsic rocks in the Mount Vermilion area.

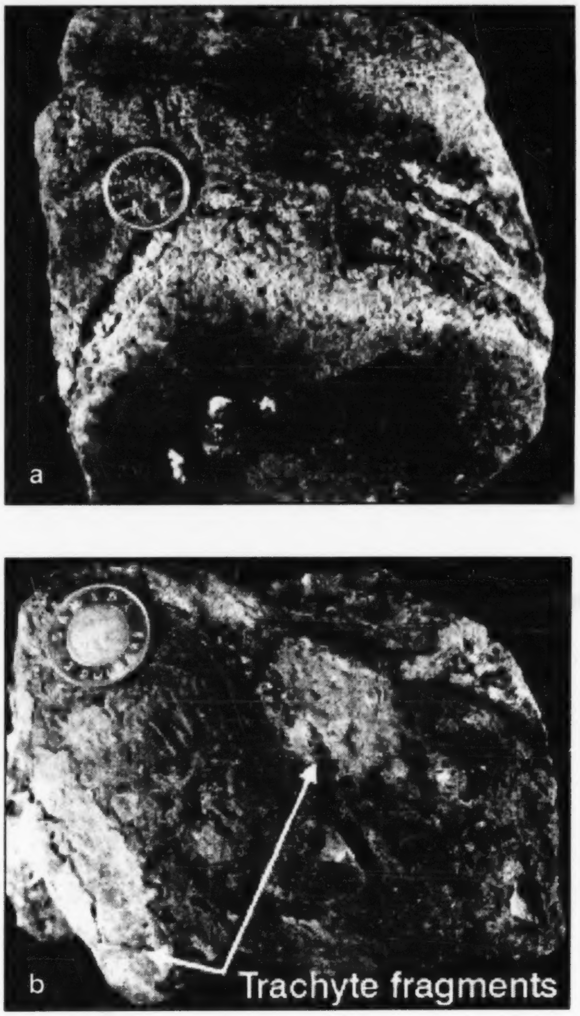


Figure 16. ***a)*** *bands of massive pyrite in trachyte;* ***b)*** *massive "frothy" pyrite with inclusions of trachyte.*

MINERALIZATION

WOLF

The Wolf Zn-Pb-Ag deposit is a tabular massive sulphide body that varies from 2 to at least 25 m thick, and has been traced for over 500 m along strike (Holbek and Wilson, 1998). The massive sulphides are primarily very fine-grained pyrite with bands of amber-coloured sphalerite and fine-grained steely-grey galena (Fig. 15). Barite appears to occur laterally, peripheral to the sulphide mineralization. In general the massive sulphides occur immediately below a feldspar phyric, locally amygdaloidal, trachyte flow within a pyritic tuff unit.

PREVIOUSLY UNREPORTED MINERALIZATION

- Massive sulphide boulders occur in a creek 4.2 km northwest of Mount Vermilion (*A on Fig. 3) and are believed to originate from a showing located about 250 m upstream. The mineralization consists of bands of massive pyrite several centimetres thick in fine-grained, silicified trachyte (Fig. 16a) and massive "frothy" pyrite with fragments of trachyte (Fig. 16b).

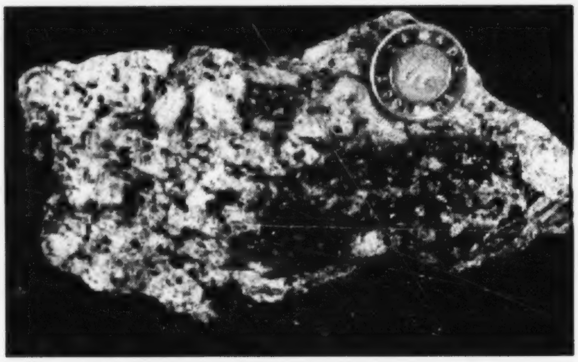


Figure 17. *Possible massive sulphide rubble in massive carbonate.*

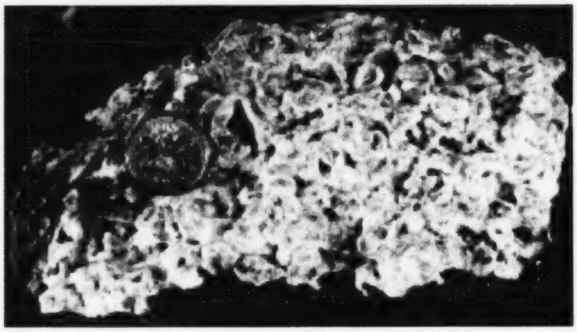


Figure 18. *Carbonate ± barite tufa.*

- Possible relict massive sulphide mineralization was found on a ridge top about 700 m south of Mount Vermilion (*B on Fig. 3). The porous, ferrous oxide rubble appears to be hosted by the carbonate sequence which overlies the volcanic succession (Fig. 17).
- Carbonate ± barite? tufa deposits were located in a creek 5.45 km northwest of Mount Vermilion (*C on Fig. 3; Fig. 18).

OTHER

Southwest of the Mount Vermilion area, mylonitized metamorphic rocks rest as a flat thrust sheet on unmetamorphosed strata of the Upper Triassic, and Upper Triassic and (?) Lower Jurassic assemblages (Gordey, 1977). On the basis of composition of the mylonitic rocks, Gordey (1977) suggested that they may be the metamorphosed and cataclastic equivalent of parts of the Devono-Mississippian volcanic assemblage. Thus this area has the potential to host massive sulphide deposits similar to Wolf.

Gordey (1977) depicts volcanic rocks, correlative to those in the Mount Vermilion area, in the Kechika map area of northern British Columbia which forms part of the Kechika Trough, the southern extension of the Selwyn Basin.

ACKNOWLEDGMENTS

The author thanks Atna staff for their cooperation, sharing of information, discussions and hospitality. YGC Resources Ltd., the owners of the Wolf claims, permitted access to the property. Trans North helicopter pilots, especially John Witham, provided safe and reliable transport and assistance. Many thanks are offered to Jason Adams, Grant Redfern and Dean Polard for helpful and enthusiastic field assistance. Thanks to Charlie Roots for editing and improving this paper.

REFERENCES

Blusson, S.L., 1976. Selwyn Basin; Yukon and District of Mackenzie. Geological Survey of Canada, Paper 76-1A, p. 131-132.

Chronic, F.J., 1979. Geology of the Guano-Guayes rare earth element bearing skarn property, Pelly Mountains, Yukon Territory. Unpublished M.Sc. Thesis, University of British Columbia, Vancouver, British Columbia, Canada, 122 p.

Doherty, A., 1997. Mamu-Bravo-Kulan claims: a VMS exploration target based on geochemical and geophysical anomalies in Mississippian volcanics within Cassiar Platform, NTS 105-F/7,8,9, & 10. *In:* Yukon Exploration and Geology 1996, Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 56-61.

Fritz, W.H., Cecile, M.P., Norford, B.S., Morrow, D. and Geldsetzer, H.H.J., 1991. Cambrian to mid-Devonian Assemblages. *In:* Geology of the Cordilleran Orogen in Canada; Geological Survey of Canada, H. Gabrielse and C.J. Yorath (eds.), Geology of Canada, no. 4., p. 151-218.

Gabrielse, H., 1967. Tectonic evolution of the northern Canadian Cordillera. Canadian Journal of Earth Sciences, vol. 4, p. 271-298.

Gabrielse, H. and Yorath, C.J., 1991. Geology of the Cordilleran Orogen in Canada. Geological Survey of Canada, Geology of Canada, no. 4., 844 p.

Gibson, A.M., Holbek, P.M. and Wilson, R.G., 1999. The Wolf property – 1998 update: Volcanogenic massive sulphides hosted by rift-related, alkaline, felsic volcanic rocks, Pelly Mountains, Yukon. *In:* Yukon Exploration and Geology 1998, C.F. Roots and D.S. Emond (eds.), Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 237-242.

Gordey, S.P., 1977. Stratigraphy structure and tectonic evolution of the southern Pelly Mountains in the Indigo Lake area, Yukon Territory. Unpublished Ph.D. Thesis, Queen's University, Kingston, Ontario, Canada, 200 p.

Gordey, S.P., 1978. Stratigraphy and structure of the Summit Lake area, Yukon Territory and District of Mackenzie. Geological Survey of Canada, Paper 78-1A, p. 43-48.

Gordey, S.P., 1979. Stratigraphy of southern Selwyn Basin in the Summit Lake area, Yukon Territory and Northwest Territories. Geological Survey of Canada, Paper 79-1A, p. 13-16.

Gordey, S.P., 1981. Stratigraphy, structure and tectonic evolution of southern Pelly Mountains in the Indigo Lake area, Yukon Territory. Geological Survey of Canada, Bulletin 318, 44 p.

Holbek, P.M. and Wilson R.G., 1998. The Wolf discovery: a Kuroko-style volcanogenic massive sulphide deposit hosted by rift-related, alkaline felsic volcanic rocks. *In:* Yukon Exploration and Geology 1997, Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 115-120.

Johnston, S.T. and Mortensen, J.K., 1994. Regional setting of porphyry Cu-Mo deposits and volcanogenic massive sulphide deposit, and mesothermal gold deposits in the Yukon-Tanana Terrane, Yukon. *In:* Abstracts and Proceedings of the District 6 Canadian Institute of Mining and Metallurgy, 1994 Annual General Meeting, J.L. Jambor (ed.), p. 30-34.

Morin, J.A., 1977. Ag-Pb-Zn mineralization in the MM deposit and associated Mississippian felsic volcanic rocks in the St. Cyr Range, Pelly Mountains. Mineral Industry Report, 1976. Yukon Territory, EGS 1977-1, Indian and Northern Affairs Canada, p. 83-97.

Mortensen, J.K., 1979. Stratigraphic, structural, and tectonic setting of an upper Devonian-Mississippian volcanic sedimentary sequence and associated base metal deposits in the Pelly Mountains, southeastern Yukon Territory. Unpublished M.Sc. Thesis, University of British Columbia, Vancouver, British Columbia, Canada, 122 p.

Mortensen, J.K., 1981. Geological setting and tectonic significance of Mississippian felsic metavolcanic rocks in the Pelly Mountains, southeastern Yukon Territory. Canadian Journal of Earth Sciences, vol. 19, p. 8-22.

Mortensen, J.K. and Godwin, C.I., 1982. Volcanogenic massive sulphide deposits associated with highly alkaline rift volcanics in the southeastern Yukon Territory. Economic Geology, vol. 77, p. 1225-1230.

Schultze, H.C., 1996. Summary of the Kudz Ze Kayah project, volcanic hosted massive sulphide deposit, Yukon Territory. *In:* Yukon Exploration and Geology 1995, Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 29-31.

Tempelman-Kluit, D.J., 1977a. Stratigraphic and structural relations between the Selwyn Basin, Pelly-Cassiar Platform, and Yukon Crystalline Terrane in the Pelly Mountains, Yukon. Geological Survey of Canada, Paper 77-1A, p. 223-227.

Tempelman-Kluit, D.J., 1977b. Quiet Lake and Finlayson Lake map areas, Yukon. Geological Survey of Canada, Open File 486 (two 1:250 000 scale maps and legend).

Tempelman-Kluit, D.J. and Blusson, S.L., 1977. Pelly-Cassiar Platform and Selwyn Basin: neither without the other. Geological Association of Canada, Annual General Meeting, 1977, Program with abstracts, vol. 2, p. 52.

Tempelman-Kluit, D.J., Gordey, S.P. and Read, B., 1976. Stratigraphic and structural studies in the Pelly Mountains, Yukon Territory. Geological Survey of Canada, Paper 76-1A, p. 97-106.

Tucker, T.L., Turner, A.J., Terry, D.A. and Bradshaw, G.D., 1997. Wolverine massive sulphide project, Yukon Territory, Canada. *In:* Yukon Exploration and Geology 1997, Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 53-55.

Wheeler, J.O., Green, L.H. and Roddick, J.A., 1960a. Quiet Lake. Geological Survey of Canada, Map 7-1960.

Wheeler, J.O., Green, L.H. and Roddick, J.A., 1960b. Finlayson Lake. Geological Survey of Canada, Map 8-1960.

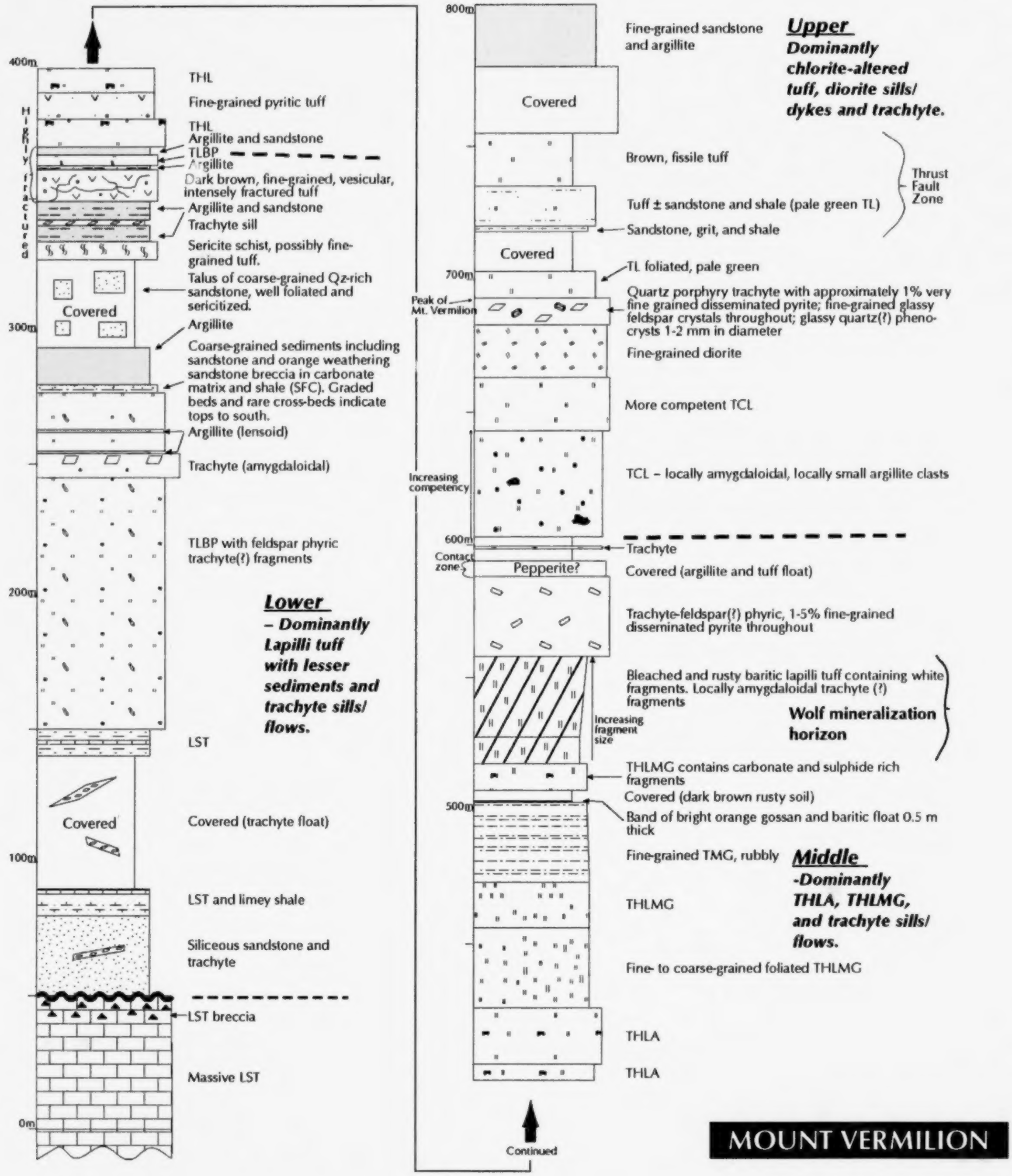
Wheeler, J.O. and McFeely, P., 1991. Tectonic Assemblage map of the Canadian Cordillera and adjacent parts of the United States of America. Geological Survey of Canada, Map 1712A, 1: 2,000,000 scale.

Yukon Minfile. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada. Also available from Hyperborean Productions, Whitehorse, Yukon.

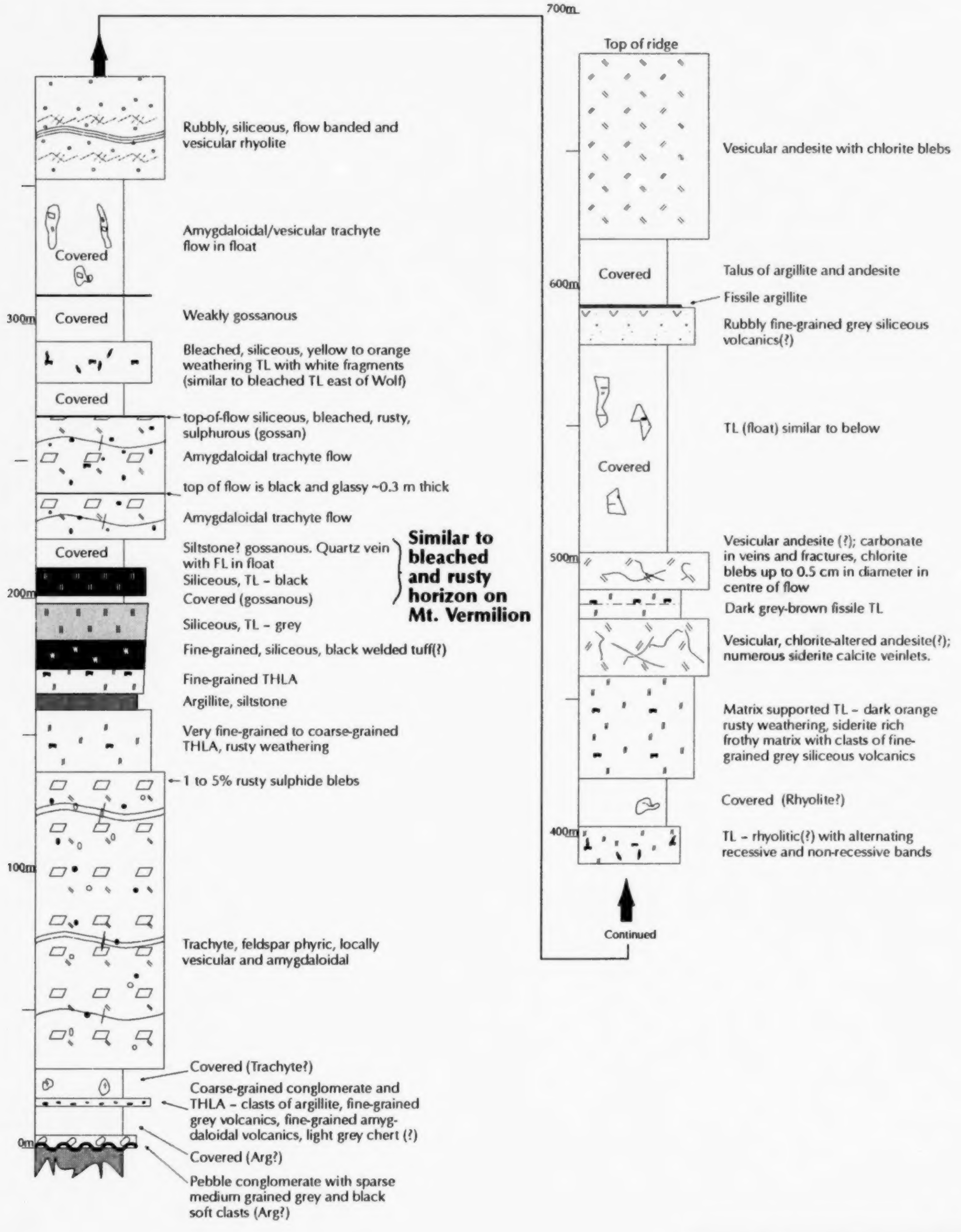
APPENDIX 1

STRATIGRAPHIC SECTIONS

Abbreviations are the same as those used in Figure 3 legend.



400m
300m
200m
100m
0m
Highly fractured
THL
Fine-grained pyritic tuff
THL
Argillite and sandstone
TLBP
Argillite
Dark brown, fine-grained, vesicular, intensely fractured tuff
Argillite and sandstone
Trachyte sill
Sericite schist, possibly fine-grained tuff.
Talus of coarse-grained Qz-rich sandstone, well foliated and sericitized.
Covered
Argillite
Coarse-grained sediments including sandstone and orange weathering sandstone breccia in carbonate matrix and shale (SFC). Graded beds and rare cross-beds indicate tops to south.
Argillite (lensoid)
Trachyte (amygdaloidal)
TLBP with feldspar phyric trachyte(?) fragments
Lower
- Dominantly Lapilli tuff with lesser sediments and trachyte sills/ flows.
LST
Covered
Covered (trachyte float)
LST and limey shale
Siliceous sandstone and trachyte
LST breccia
Massive LST
800m
700m
600m
500m
Fine-grained sandstone and argillite
Upper
Dominantly chlorite-altered tuff, diorite sills/ dykes and trachtyte.
Covered
Brown, fissile tuff
Thrust Fault Zone
Tuff ± sandstone and shale (pale green TL)
Sandstone, grit, and shale
Covered
TL foliated, pale green
Peak of Mt. Vermilion
Quartz porphyry trachyte with approximately 1% very fine grained disseminated pyrite; fine-grained glassy feldspar crystals throughout; glassy quartz(?) phenocrysts 1-2 mm in diameter
Fine-grained diorite
More competent TCL
Increasing competency
TCL - locally amygdaloidal, locally small argillite clasts
Trachyte
Contact zone
Pepperite?
Covered (argillite and tuff float)
Trachyte-feldspar(?) phyric, 1-5% fine-grained disseminated pyrite throughout
Bleached and rusty baritic lapilli tuff containing white fragments. Locally amygdaloidal trachyte (?) fragments
Increasing fragment size
Wolf mineralization horizon
THLMG contains carbonate and sulphide rich fragments
Covered (dark brown rusty soil)
Band of bright orange gossan and baritic float 0.5 m thick
Fine-grained TMG, rubbly
Middle
-Dominantly THLA, THLMG, and trachyte sills/ flows.
THLMG
Fine- to coarse-grained foliated THLMG
THLA
THLA
Continued
MOUNT VERMILION


Rubbly, siliceous, flow banded and vesicular rhyolite
Covered
Amygdaloidal/vesicular trachyte flow in float
300m
Covered
Weakly gossanous
Bleached, siliceous, yellow to orange weathering TL with white fragments (similar to bleached TL east of Wolf)
Covered
top-of-flow siliceous, bleached, rusty, sulphurous (gossan)
Amygdaloidal trachyte flow
top of flow is black and glassy ~0.3 m thick
Amygdaloidal trachyte flow
Covered
Siltstone? gossanous. Quartz vein with FL in float
Siliceous, TL - black
200m
Covered (gossanous)
Siliceous, TL - grey
Similar to bleached and rusty horizon on Mt. Vermilion
Fine-grained, siliceous, black welded tuff(?)
Fine-grained THLA
Argillite, siltstone
Very fine-grained to coarse-grained THLA, rusty weathering
1 to 5% rusty sulphide blebs
100m
Trachyte, feldspar phyric, locally vesicular and amygdaloidal
Covered (Trachyte?)
Coarse-grained conglomerate and THLA - clasts of argillite, fine-grained grey volcanics, fine-grained amygdaloidal volcanics, light grey chert (?)
0m
Covered (Arg?)
Pebble conglomerate with sparse medium grained grey and black soft clasts (Arg?)
700m
Top of ridge
Vesicular andesite with chlorite blebs
600m
Covered
Talus of argillite and andesite
Fissile argillite
Rubbly fine-grained grey siliceous volcanics(?)
TL (float) similar to below
Covered
500m
Vesicular andesite (?); carbonate in veins and fractures, chlorite blebs up to 0.5 cm in diameter in centre of flow
Dark grey-brown fissile TL
Vesicular, chlorite-altered andesite(?); numerous siderite calcite veinlets.
Matrix supported TL - dark orange rusty weathering, siderite rich frothy matrix with clasts of fine-grained grey siliceous volcanics
Covered (Rhyolite?)
400m
TL - rhyolitic(?) with alternating recessive and non-recessive bands
Continued

CENTRAL AREA

Preliminary geology of Rose Mountain, Anvil District, central Yukon (105K/05)

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Pigage, L., 1999. Preliminary geology of Rose Mountain, Anvil District, central Yukon (105K/05). *In:* Yukon Exploration and Geology 1998, C.F. Roots and D.S. Emond (eds.), Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 91-103.

ABSTRACT

A 2000 m thick succession of six metasedimentary and metavolcanic units ranging in age from Ordovician through Permian strikes northwest and dips moderately to the southwest in the Rose Mountain area (105K/05). Units 3-6 have conformable contacts exposed and form a continuous succession. Units 1, 2 and 4 are correlated with lower to middle Paleozoic regional stratigraphic units of ancestral North America. Unit 3 consists of pale green argillite with lesser chert pebble conglomerate, sandstone and shale chip breccia interbeds, and is unique to the Rose Mountain area. Unit 5 is bedded chert and is correlated with North American Mount Christie Formation. Unit 5 is also similar to chert units in Slide Mountain Terrane. Unit 6 correlates with basalts of the Slide Mountain Terrane.

Unit 4 is correlated with Earn Group and contains two stratiform barite horizons. No sulphides are visibly associated with the barite, but the unit is favourable for stratiform base metal mineralization.

All units contain one major deformation fabric. This contrasts with structural style immediately to the northeast where two major deformation fabrics occur. The Rose Mountain fabric is correlated with the older deformation fabric present to the northeast.

RÉSUMÉ

Une succession de six unités de roches métasédimentaires et métavolcaniques datant de l'Ordovicien au Permien d'une épaisseur de 2000 mètres est orientée au nord-ouest et présente un pendage modéré en direction du sud-ouest dans la région du mont Rose (105K/05). Les unités 3 à 6 présentent des contacts concordants qui sont exposés et constituent une succession continue. Les unités 1, 2 et 4 sont en corrélation avec les unités stratigraphiques régionales du Paléozoïque inférieur à moyen du protocontinent nord-américain. L'unité 3 consiste en argilite vert pâle avec de moindres interlits de conglomérat à cailloux de chert, de grès et de brèche à éclats de shale et ne se retrouve que dans la région du mont Rose. L'unité 5 présente des affinités et avec le protocontinent nord-américain et avec le terrane de Slide Mountain. L'unité 6 est en corrélation avec les basaltes du terrane de Slide Mountain.

Deux horizons de barytine stratiforme ont été documentés dans l'unité 4, qui est en corrélation avec le groupe d'Earn. Bien que la pyrite ne soit pas associée de manière visible à la barytine, la stratigraphie de l'unité 4 est favorable à la minéralisation stratiforme de métaux communs.

Une structure de déformation majeure touche toutes les unités, ce qui contraste avec le style structural présent immédiatement au nord-est qui est caractérisé par deux structures de déformation majeures. La structure du mont Rose est en corrélation avec les structures de déformation plus anciennes présentes au nord-est.

INTRODUCTION

The Anvil District (Figs. 1, 2) in central Yukon contains five known pyritic massive sulphide deposits (Faro, Grum, Vangorda, Grizzly, and Swim) with a total mineral inventory of 120.1 million tonnes averaging 9.3% combined lead and zinc, and two uneconomic pyritic sulphide occurrences (SB and Sea; Jennings and Jilson, 1986). The deposits were discovered between 1953 and 1976. Faro and Vangorda have been mined, Grum is partly mined, and Grizzly and Swim have not yet been developed.

Exploration potential in the district remains high. The Anvil Project is a new, multi-disciplinary study commissioned by the Yukon Geology Program to provide a unified geological framework for the Anvil District to assist future exploration. Projects within this integrated study include bedrock geology mapping and compilation (this report), surficial geology mapping and basal till sampling (see Bond, this volume), detailed lithogeochemistry of the immediate host rocks to the massive sulphide deposits, and a seismic reflection profile over the Grizzly deposit. These projects began in 1998.

The goal of the bedrock mapping and geological compilation of the district is to bridge the gap between detailed property-scale geology mapping of exploration companies and regional geology mapping of the Geological Survey of Canada. Geology will be presented on a series of maps at a scale of 1:25 000. A significant portion of this project will consist of re-interpretation, harmonization, and consolidation of the detailed geological information from the 45-year exploration history.

One month was spent in the field during 1998 conducting bedrock geological mapping, including eight days of traverses on the southeast and northwest flanks of Rose Mountain (Figs. 2, 3, 4 and 5). This report details the stratigraphy and structure observed on Rose Mountain. All descriptions are based on field and hand sample observations; samples have been sent for geochemical and chronological analysis.

LOCATION AND ACCESS

Rose Mountain (NTS map 105K/05) is located 19.5 km northwest of the Town of Faro and 12.5 km west of the Faro minesite in central Yukon. Rose Creek flows west into Anvil Creek on the north edge of the area, and the Pelly River flows to the northwest in Tintina Trench, a major northwest-trending physiographic feature immediately south of the area. Tree line occurs at the approximate elevation of 4500 ft (1370 m). Outcrop is extensive on ridges above tree line. Below tree line, outcrop is generally restricted to stream cuts and scattered ridge crests. Valley bottoms are typically covered with thin to thick glacial till.

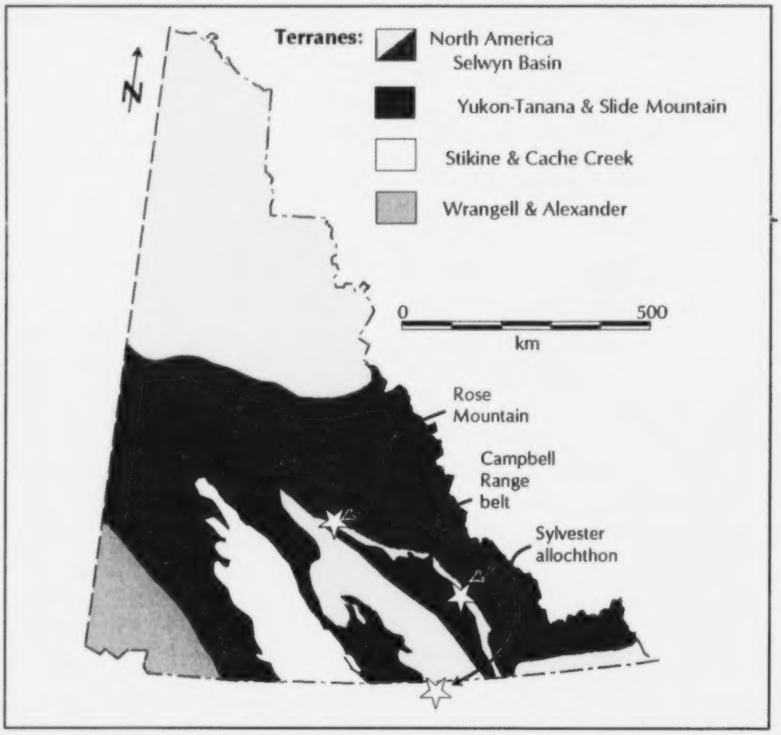


Figure 1. *Locations of Rose Mountain in Anvil District (Fig. 2), Campbell Range belt, and Sylvester allochthon. Modified from Wheeler and McFeely (1987).*

Overgrown exploration roads extend to the southeastern and northern margins of Rose Mountain. Outfitting trails lead into the area for hunting. Access is most readily accomplished by helicopter. Camps during 1998 were placed using contract helicopter services out of Ross River.

PREVIOUS WORK

Rose Mountain lies within Tay River map area (105K), where the regional geology was mapped by Roddick and Green (1961) and Gordey and Irwin (1987). The discovery of the massive sulphide deposits in the Anvil District led to more detailed geology studies by Tempelman-Kluit (1972) and Gordey (1990).

Early exploration activity near Rose Mountain occurred dominantly on the lower slopes of Rose Creek valley and was focussed toward lead-zinc targets because of the Faro discovery. In 1977 Cyprus Anvil Mining Corporation staked the URN claims over two barite horizons on the northeast-facing slopes of Rose Mountain.

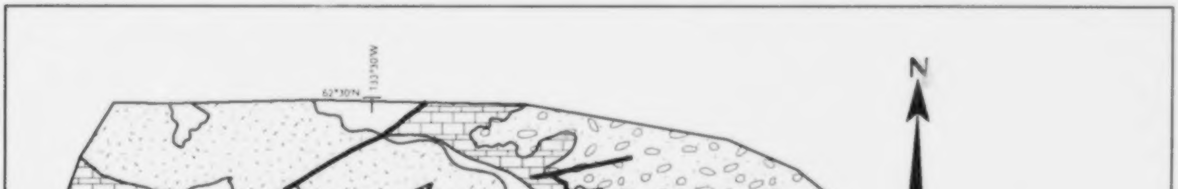
The URN barite horizons were sampled in 1977 (Franzen, 1978) and 1981 (Read, 1982) for their industrial mineral potential. Yukon Minfile 105K 106 summarizes the URN barite exploration work.

REGIONAL GEOLOGY

Rose Mountain is located on the southwest flank of the Anvil District (Fig. 2) in central Yukon. Anvil District is part of the Cordilleran miogeocline, a prism of sedimentary rocks of Precambrian to Jurassic age deposited along the relatively stable continental margin of western North America. Cordilleran miogeocline stratigraphy is presented in Abbott et al. (1986), and more detailed stratigraphy and structure in the Anvil District is given in Jennings and Jilson (1986) and Pigage (1990).

Anvil District is immediately east of the Yukon-Tanana Terrane (Coney et al., 1980), the easternmost of the accreted suspect terranes. The Yukon-Tanana Terrane is juxtaposed against Anvil District along the Vangorda fault (Jennings and Jilson, 1986) which Mortensen and Jilson (1985) have interpreted as a transpressive suture. Deformation and metamorphism associated with accretion of the suspect terranes was initiated during the Jurassic and culminated in the Cretaceous period (Tempelman-Kluit, 1979). More recently, strike-slip faulting along the Tintina Fault zone immediately southwest of Rose Mountain resulted in 450-500 km of right lateral strike-slip displacement during late Cretaceous-early Tertiary time (Tempelman-Kluit, 1970).

Tempelman-Kluit (1972) mapped four southwest-dipping units on Rose Mountain. The two lowermost units outcrop on the lower slopes of Rose Mountain and consist of chlorite-quartz-muscovite phyllite overlain by grey slate. These units were tentatively assigned ages of Hadrynian to Ordovician, and Devonian to Mississippian, respectively. They were conformably overlain by the Anvil Range Group, a succession consisting of a lower member containing interbedded cherts and coarse clastic rocks, and an upper unit consisting of mafic volcanic rocks with lesser interbedded cherts. Fossils from the lower unit allowed an age assignment of Pennsylvanian through Permian for both units. The uppermost member of the Anvil Range Group, as defined by Tempelman-Kluit, does not occur in the Rose Mountain area. Tempelman-Kluit (1979) considered the Anvil



62°30'N
133°30'W
N
ANVIL BATHOLITH
FARO
Figure 3
TINTINA FAULT
GRUM
VANGORDA
GRIZZLY
SWIM
SB
SEA
62°15'N
133°00'W
62°15'N
Faro
LEGEND
Anvil Batholith - granite
Anvil Range Group - chert, basalt, ultramafics
Lower Paleozoics - shale, chert, volcanics
Vangorda formation - calcareous phyllite, calc-silicate, greenstone
Mt Mye formation - phyllite, schist
Yukon-Tanana "suspect" terrane
Sulphide deposit
Fault
0
5
10
20
km

Figure 2. *Schematic geology of Anvil District, Yukon, showing the Rose Mountain area (Fig. 3). Modified from Jennings and Jilson (1986).*

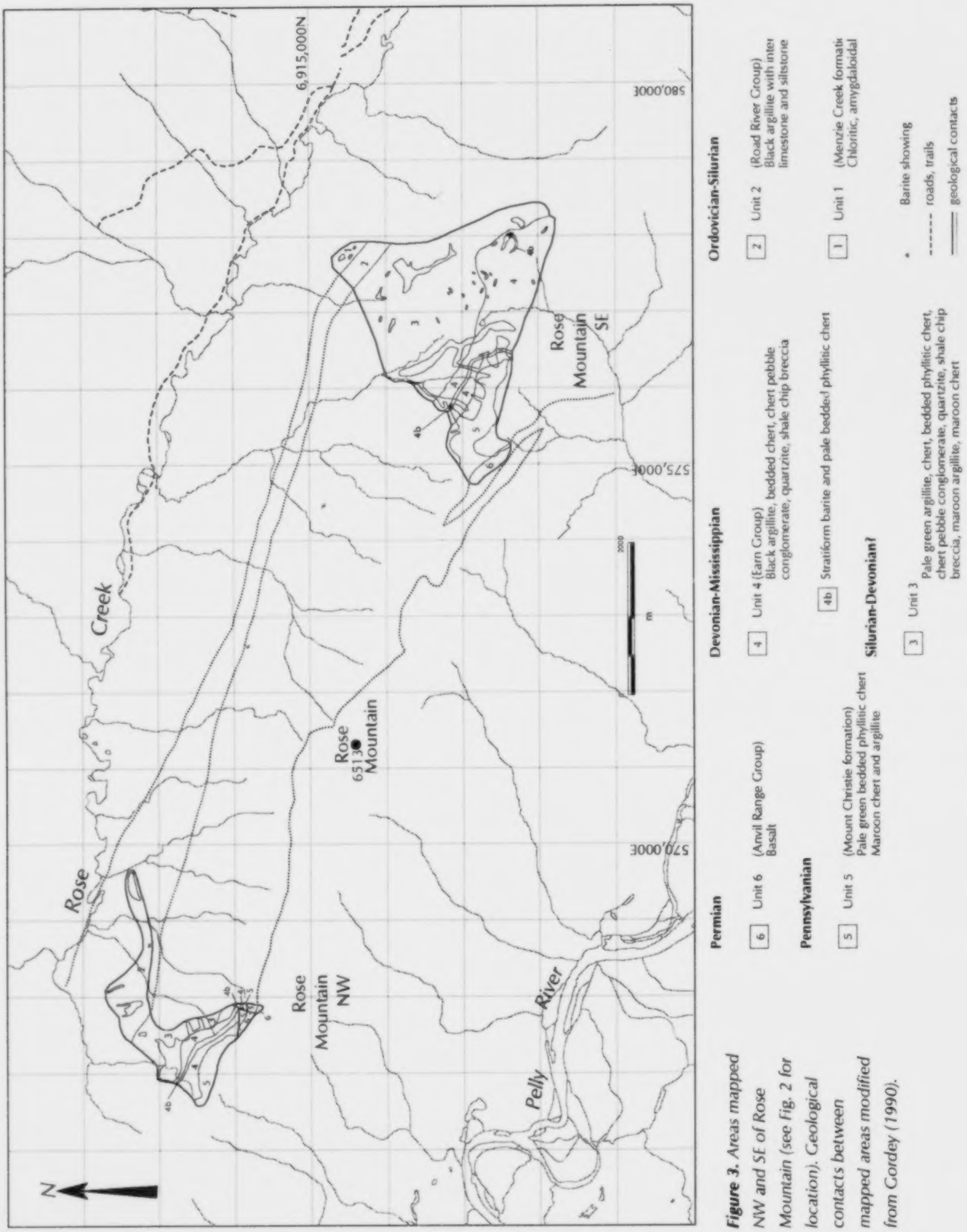

N
Rose
Creek
6,915,000N
580,000E
575,000E
570,000E
Rose
6513
Mountain
Rose
Mountain
NW
Rose
Mountain
SE
Pelly
River
2000
m
4b
4
5
6
3
2
1
Permian
6 Unit 6 (Anvil Range Group)
Basalt
Pennsylvanian
5 Unit 5 (Mount Christie formation)
Pale green bedded phyllitic chert
Maroon chert and argillite
Devonian-Mississippian
4 Unit 4 (Earn Group)
Black argillite, bedded chert, chert pebble
conglomerate, quartzite, shale chip breccia
4b Stratiform barite and pale bedded phyllitic chert
Silurian-Devonian?
3 Unit 3
Pale green argillite, chert, bedded phyllitic chert,
chert pebble conglomerate, quartzite, shale chip
breccia, maroon argillite, maroon chert
Ordovician-Silurian
2 Unit 2 (Road River Group)
Black argillite with inter
limestone and siltstone
1 Unit 1 (Menzie Creek formatic
Chloritic, amygdaloidal
• Barite showing
------ roads, trails
—— geological contacts

Figure 3. *Areas mapped NW and SE of Rose Mountain (see Fig. 2 for location). Geological contacts between mapped areas modified from Gordey (1990).*

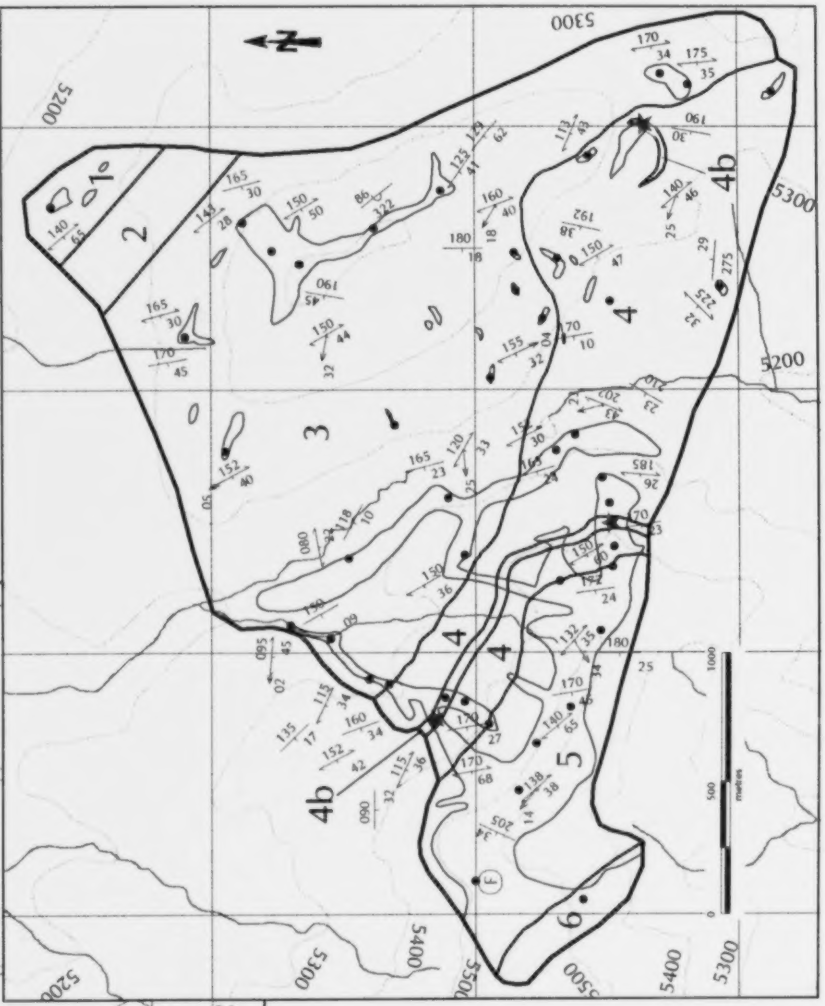

1°
2
3
4
4b
5
6
F
5200
5300
5400
5500
0
500
1000
metres

Figure 5. Geology of Rose Mountain SE area (see legend in Fig. 3).

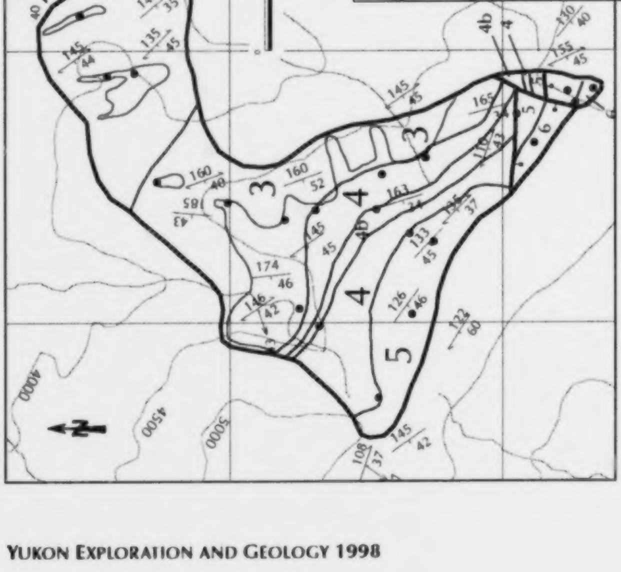

Rose Creek
2
3
4
4b
5
6
3500
4000
4500
5000
0
500
1000
metres

Figure 4. Geology of Rose Mountain NW area (see legend in Fig. 3).

Range Group as autochthonous at Rose Mountain, and suggested that it was an intact correlative unit of the major Anvil allochthonous assemblage.

Gordey (1990) correlated the units mapped by Tempelman-Kluit to regional stratigraphy mapped southwest and northeast of Rose Mountain. The two lower units were correlated with Ordovician Menzie Creek formation and Ordovician-Silurian Duo Lake Formation, respectively. These units are an integral part of the early Paleozoic North American miogeocline. In contrast, the Anvil Range Group was correlated with the Anvil allochthonous assemblage and considered to be an obducted slice of oceanic terrane emplaced on North American stratigraphy during Mesozoic accretion of suspect terranes to North America.

Geologists working for Cyprus Anvil Mining Corporation suggested that at least part of the Anvil Range Group had North American affinities and was autochthonous (Jennings and Jilson, 1986). They were unable to identify a location for the required thrust fault flooring an obducted sequence (G. Jilson, pers. comm., 1998).

The 1998 traverses suggest that the Rose Mountain stratigraphy represents a structurally concordant succession of stratigraphic units. Several of these units can be correlated with regional North American stratigraphic units, implying that the entire Rose Mountain stratigraphy has North American affinities. At the same time the two uppermost units previously mapped as Anvil Range Group are similar to correlative units in Campbell Range belt and Sylvester allochthon (Fig. 1). In these latter areas, the correlative units have been mapped and interpreted as Slide Mountain Terrane. Further work is needed to clarify the similarity of Anvil Range Group lithologies to successions in both North American and Slide Mountain Terranes.

ROSE MOUNTAIN GEOLOGY

INTRODUCTION

Figure 3 shows geological mapping completed during 1998 on the southeast and northwest ends of Rose Mountain. The two areas are located approximately 10 km apart but have similar

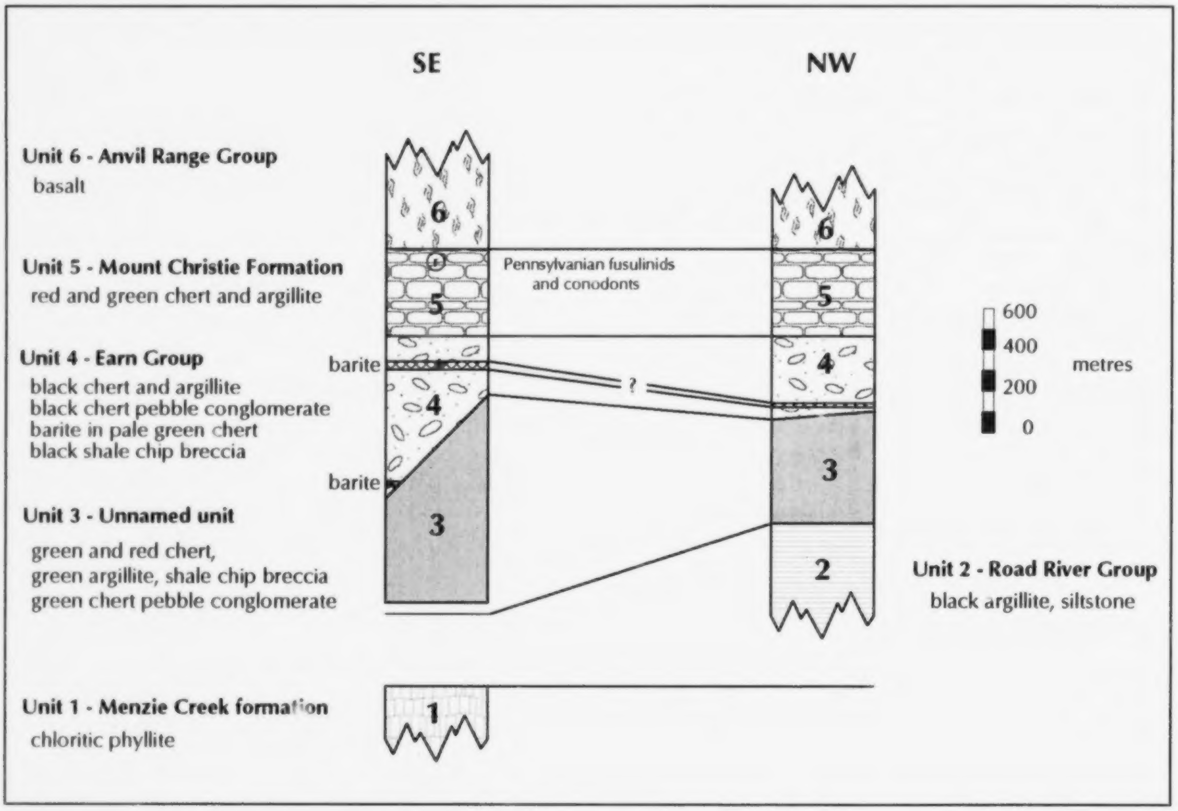

SE
NW
Unit 6 - Anvil Range Group
basalt
Unit 5 - Mount Christie Formation
red and green chert and argillite
Unit 4 - Earn Group
black chert and argillite
black chert pebble conglomerate
barite in pale green chert
black shale chip breccia
Unit 3 - Unnamed unit
green and red chert,
green argillite, shale chip breccia
green chert pebble conglomerate
Unit 1 - Menzie Creek formation
chloritic phyllite
Unit 2 - Road River Group
black argillite, siltstone
Pennsylvanian fusulinids
and conodonts
barite
barite
?
6
5
4
3
1
6
5
4
3
2
600
400
200
0
metres

Figure 6. Stratigraphic columns for mapped areas on Rose Mountain.

stratigraphy. Figures 4 and 5 are detailed geology maps for the areas, and Figure 6 presents a combined stratigraphic column based on the geology maps.

Six northwest-trending stratigraphic units form a 2000 m thick succession that uniformly dips moderately to the southwest, with an average orientation of 164°/32°SW. The succession overlies Hadrynian-Cambrian pelites and calcareous pelites of the North American miogeocline. West of the uppermost unit, the succession is bounded by mafic and ultramafic units constituting the Vangorda fault zone (Jennings and Jilson, 1986; Gordey, 1990).

All units contain a single deformation foliation (S_1) consisting of either a slaty cleavage (argillite) or a spaced fracture cleavage (chert). The S_1 foliation also trends northwest and dips southwest (average orientation 147°/37°SW) more steeply than the S_0 bedding. Stratigraphic thicknesses are a minimum because of the pervasive S_1 foliation. The entire sequence is interpreted to be structurally upright with northeast vergence. Stratigraphic tops from rare graded beds are consistent with this structural interpretation. Scattered outcrops with overturned S_0 bedding denote local macroscopic parasitic folds within the generally upright succession. Minor folds were not observed.

To the northeast, closer to the Anvil Batholith, metasedimentary and metavolcanic rocks contain two pervasive deformation foliations (Jennings and Jilson, 1986). This contrasts with the one foliation present in the Rose Mountain area. Detailed studies have demonstrated that the second foliation developed concurrently with emplacement of the Anvil Batholith during Cretaceous time (Pigage and Anderson, 1985; Jennings and Jilson, 1986; Smith and Erdmer, 1990). These studies also showed that the second deformation fabric decreased rapidly in intensity laterally away from the batholith. The timing of development of the first foliation is loosely constrained to be post upper Paleozoic (Jennings and Jilson, 1986). Based on orientation and distance from the Anvil Batholith, the pervasive Rose Mountain foliation is correlated with the earlier foliation adjacent to the batholith.

The Rose Mountain area is within the muscovite-chlorite zone of greenschist facies metamorphism. Qualitatively, individual mica and chlorite grains are not readily visible, even with a hand lens.

STRATIGRAPHY

UNIT 1 - MENZIE CREEK FORMATION

Medium green, pervasively foliated, noncalcareous to slightly calcareous chloritic phyllite is exposed SE of Rose Mountain. The unit commonly contains pale tan to white calcite amygdules up to 1 cm across. Epidote locally forms irregular apple green patches. Dark green streaks are locally visible on the S_1 foliation surface. Although primary structures have been largely destroyed by deformation, Unit 1 is interpreted as an amygdaloidal volcanic basalt unit.

Jennings and Jilson (1986) and Gordey (1990) mapped a continuous northwest-trending band of this unit along the lower slopes of Rose Creek valley. It conformably overlies calcareous phyllites and calc-silicate rocks of the informal Cambrian-Ordovician Vangorda formation (Jennings and Jilson, 1986) and is conformably overlain by black phyllites correlated with Road River Group. Both contacts have been mapped regionally as interbedded with an interval of alternating pelitic phyllite and chloritic phyllite. The upper contact with the overlying unit is not exposed in the SE area, and the lower contact is outside of the map limit in both areas.

Unit 1 is similar in both lithology and stratigraphic position to the lesser deformed Menzie Creek formation (Jennings and Jilson, 1986; Gordey, 1990) which occurs on the northeast side of the Anvil Batholith. These northeastern volcanic rocks are interlayered with black phyllites containing Ordovician graptolites (Tempelman-Kluit, 1972; Gordey, 1983). On the basis of this similarity, Unit 1 is correlated with the informal Menzie Creek formation of Jennings and Jilson (1986). Similar volcanic rocks have been described in several localities in the northern Cordillera (Goodfellow et al., 1995).

UNIT 2 - ROAD RIVER GROUP (DUO LAKE FORMATION)

Unit 2 consists of black, carbonaceous, silty argillites with subordinate siltstones, sandstones, and limestones. It is exposed in the NW area (Fig. 4); the expected location of Unit 2 in the SE area does not contain any outcrop (Fig. 5).

The carbonaceous argillites (Fig. 7) are indistinctly bedded on a scale of 15 to 30 cm. They weather with a patchy deep orange-brown surface coating, although locally the weathered surface has a slight bluish grey tinge. Medium grey, tan weathering, noncalcareous siltstone to fine sandstone is interbedded with

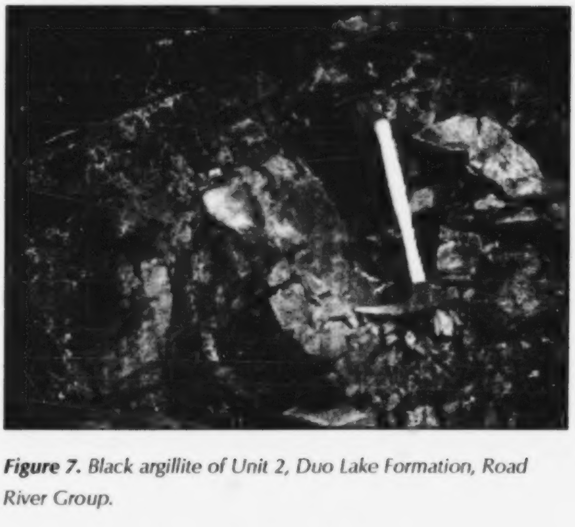


Figure 7. *Black argillite of Unit 2, Duo Lake Formation, Road River Group.*

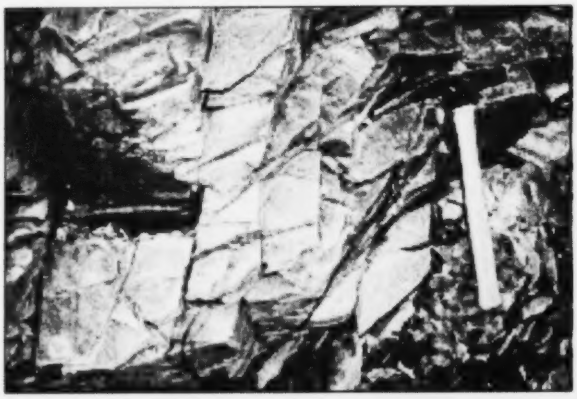


Figure 8. *Pale green argillite of Unit 3.*

the carbonaceous argillites on a scale of centimetres to tens of metres. Thick siltstone beds are more prominent near the top of Unit 2. Locally, the siltstones contain thin calcareous intervals. In places they contain a fine millimetre-scale colour pinstriping between light and dark grey. Unit 2 also locally contains silty, dark grey, argillaceous limestone interbeds up to 10 m thick.

The argillites contain a pervasive S_1 deformation foliation which forms a slightly irregular surface. They break on both the S_0 bedding and S_1 foliation surfaces.

Unit 2 is approximately 440 m thick in the NW area. The upper contact with Unit 3 is not exposed, and the lower contact with Unit 1 is outside the map limit. Unit 2 is similar in lithology and in stratigraphic position to the Duo Lake Formation (Cecile, 1982) as mapped by Gordey (1990) on the northeast side of Anvil Batholith. Middle Ordovician to early Silurian graptolites have been found in the Duo Lake Formation northeast of the batholith (Tempelman-Kluit, 1972; Gordey, 1983).

UNIT 3

Overlying the carbonaceous argillites is a mixed unit consisting dominantly of pale silvery grey-green, noncalcareous, silty argillite with lesser amounts of grey sandstone, pale green bedded and massive cherts, maroon chert and argillite, pale green chert pebble conglomerate, and pale green shale chip breccia. These lesser lithologies are interbedded with the green argillite on a scale ranging from a few centimetres to tens of metres. Sandstones, conglomerates, and breccias are much more common in the SE area where they constitute up to 50% of the unit. In contrast, the NW area contains largely the pale green argillite. Maroon rocks are restricted to exposures in the SE area and occur largely at the top and bottom of the unit. Bedded cherts occur dominantly near the top of the unit; massive cherts are scattered in minor amounts through the entire unit as beds up to 1 m thick.

The predominant argillite (Fig. 8) is soft and weathers with a patchy, medium brown surface coating. Bedding is locally marked by subtle centimetre-scale colour banding caused by thin pale grey to tan siltstone interbeds. It is pervasively foliated with a smooth S_1 foliation surface. Chert pebble conglomerates (Fig. 9) contain matrix-supported, subangular to angular clasts of pale green to white chert, light greenish grey siltstone, and minor dark grey to black chert or argillite in a silty to sandy matrix. Clasts up to 3 cm across are strongly flattened in the plane of the foliation with aspect ratios ranging from 2:1 to 8:1. Sandstone interbeds within the argillite are generally medium to dark greenish grey and have an indistinct bedding defined by variations in shades of grey. Locally, the bedding has a pinstriped appearance. Shale-chip breccias contain numerous siltstone and shale clasts which are visible on the slightly irregular S_1 foliation surface. Crude, large-scale graded bedding can be seen locally with conglomerate passing upwards to sandstone and then siltstone. Bedded cherts are rhythmically bedded with 15-20 cm pale cream to green chert alternating with thin pale green argillite interbeds.

Unit 3 ranges in thickness from 500 m to 1000 m. The thickest section occurs in the SE area and contains abundant sandstone, chert pebble conglomerate, and shale-chip breccia interbedded with argillite. The lower contact with Unit 2 is not exposed in the NW area. In the SE area a 200 m covered interval separates exposures of Unit 3 from Unit 1; Unit 2 is assumed to occur in this covered interval.

The upper contact of Unit 3 with Unit 4 is transitional with interbedding of pale green and dark grey lithologies, and mixing of pale green and dark grey to black clasts within the sandstones and conglomerates of both Units 3 and 4. The thickness of Unit 3 is inversely proportional to the thickness of Unit 4 in the SE area.

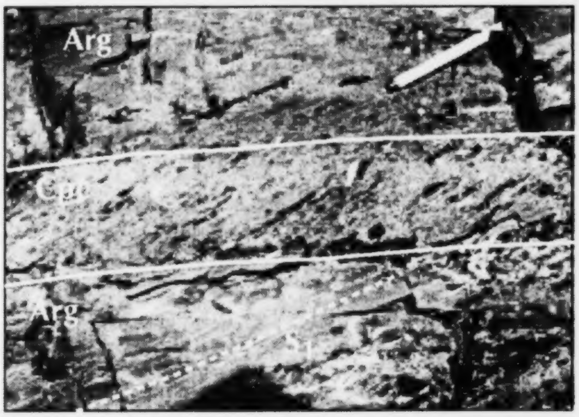
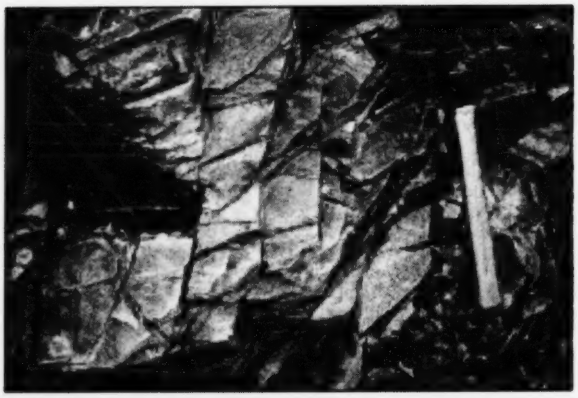


Figure 9. *Chert pebble conglomerate (cpc) interval in argillite (arg) of Unit 3. Foliation (S_1) crosses from lower left to upper right.*



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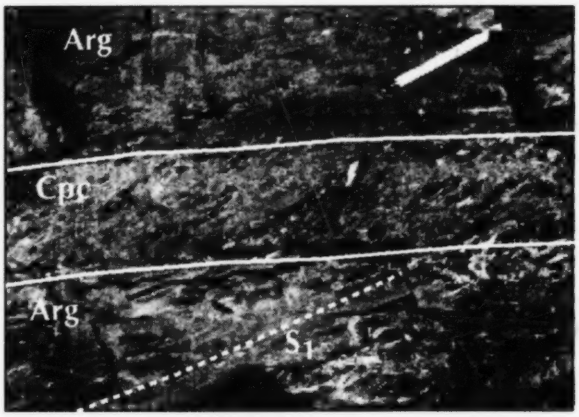

Figure 9. Chert pebble conglomerate (cpc) interval in argillite (arg) of Unit 3. Foliation (S_1) crosses from lower left to upper right.

Unit 3 does not readily correlate with known Lower Paleozoic regional stratigraphy of the North America Cordilleran miogeocline (Abbott et al., 1986; Gordey and Anderson, 1993). Strata similar to Unit 3 were not described from the northeast side of Anvil Batholith (Jennings and Jilson, 1986; Gordey, 1990). Roddick and Green (1961), however, mentioned minor green, pink, and red chert within a Road River succession in the Sheldon Lake map area (105J), 100 km northeast of Rose Mountain. Unit 3 could possibly correlate with bioturbated, pale grey siltstones of the Silurian Steel Formation (Gordey and Anderson, 1993).

It is possible, however, that Unit 3 is part of the Devonian-Mississippian Earn Group (Gordey et al., 1982) succession which unconformably overlies the Lower Paleozoic miogeocline succession. Although the pale green and maroon colours in Unit 3 are not characteristic of Earn Group, the coarse clastic component of Unit 3 lithologically resembles Earn Group rocks. Older strata with similar colours in the miogeocline occur in the latest Precambrian to Cambrian Narchilla Formation of the Hyland Group (Gordey and Anderson, 1993). Gordey and Anderson (1993) identified an area in northeast Tay River map area (105K) approximately 100 km northeast of Rose Mountain, where Earn Group rests unconformably on Hyland Group strata. The Hyland and overlying Road River strata would be a reasonable source for the material constituting Unit 3. The suggested southwest transport direction, however, does not correspond to sparse paleocurrent indicators from Earn Group in the Nahanni map area (105I) which indicate a general southeast transport direction for Earn Group conglomerates and sandstones.

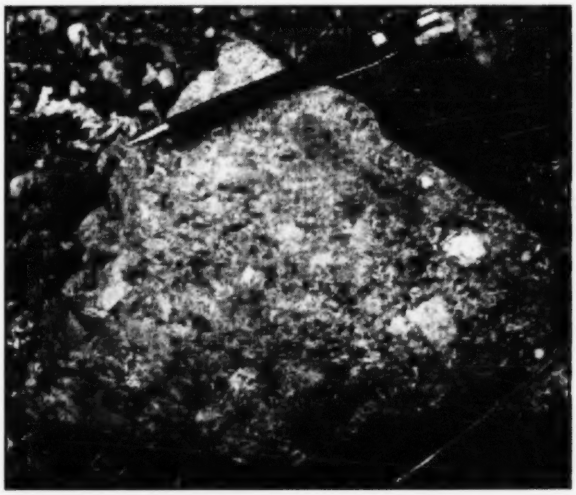

***Figure 10**. Chert pebble conglomerate in Unit 4 – Earn Group.*

Unit 3 also cannot be readily correlated with stratigraphy in Yukon-Tanana Terrane (cf. Mortensen, 1992; Murphy, 1998), Sylvester allochthon (Nelson and Bradford, 1993), or Campbell Range belt (Plint and Gordon, 1997), all of which have at various times been considered possible extensions of the Anvil allochthonous rocks.

UNIT 4 - EARN GROUP

A dark grey to black, mixed unit consisting of interbedded noncalcareous silty argillite, sandstone, shale chip breccia, chert pebble conglomerate, phyllitic bedded chert, pale green phyllitic bedded chert, and stratiform barite constitutes Unit 4. These rock types are interbedded on a scale of centimetres to tens of metres. Proportions of the different lithologies within Unit 4 vary greatly both laterally and vertically. The unit is readily recognized from a distance because the various carbonaceous rock types weather with a characteristic pale grey to bluish grey surface coating.

Black, silty argillite with lesser black bedded chert is the dominant rock type. Bedded cherts are rhythmically bedded with 5-20 cm thick black chert bands alternating with thin dark grey to black argillite interbeds. The NW area consists almost entirely of argillite and/or bedded chert. The lower part of Unit 4 in one exposure in the NW area consists of a 60 m interval with black siliceous argillite alternating with medium to dark grey, finely laminated limestone; individual beds range up to 30 cm in thickness. The limestones have been sampled for possible microfossils.

Chert pebble conglomerate successions, interbedded with thin argillite intervals, range up to 50 m in thickness. Typically the conglomerates contain predominantly dark grey to black chert, light to dark grey siltstone, and lesser pale grey to white chert clasts in a sandy to silty matrix (Fig. 10). Clasts are flattened within the S_1 foliation and may range up to 10 cm in length, although 1-2 cm lengths are most common. Thick conglomerate beds are restricted to the lower half of Unit 4 in the SE area; thin conglomerate beds occur through the entire unit in the SE area. Only one 2 m thick conglomerate was noted in the NW area. Commonly the conglomerates are interbedded with shale chip breccias which contain dark to light grey flattened siltstone clasts in a silty argillite matrix. At the base of Unit 4 in the SE area, the conglomerate and shale chip breccia include pale green argillite and/or chert clasts and are interbedded with pale green argillite, chert, and shale chip breccia. Exposures of dark grey quartzite up to 3 m high also occur in the basal part of Unit 4 in the SE area.

In the SE area, Unit 4 contains two stratiform to nodular barite horizons (Yukon Minfile 105K 106, URN) separated by a stratigraphic interval of approximately 600 m. Both barite horizons occur within pale cream to silvery green phyllitic bedded chert intervals ranging up to 40 m in thickness. No pyrite is visibly associated with the barite. The barites contain the same pervasive S_1 deformation foliation as the enclosing cherts and argillites (Fig. 11). Both horizons have previously been sampled for possible use in drilling mud (Franzen, 1978; Read, 1982). The major gangue mineral with the barite is quartz, and the barite would have to be concentrated for industrial drilling mud use. The barite occurrences have been sampled for sulphur isotopic analysis.

In the Rose Mountain area, Unit 4 ranges in thickness from 300 to 900 m. The upper contact with the overlying Unit 5 is conformable. In the SE area the contact is sharp, and in the NW area the contact is transitional with interbedding of lithologies for a 20 m interval. The contact is placed at the top of the last dark grey to black bed. The lower contact is transitional in both the NW and SE areas with interbedding of lithologies for an interval ranging up to 20 m in thickness. The contact is placed at the lowermost interval with argillite and/or the silty matrix in conglomerate being dark grey to black.

Unit 4 is correlated with the middle Devonian to Mississippian Earn Group (Gordey et al., 1982) on the basis of lithologic similarity and stratigraphic position. The pale grey weathering colours, coarse clastic lithologies, and presence of stratiform barite are typical. The same unit as described by Gordey (1990) and Jennings and Jilson (1986) is also present on the northeast side of the Anvil Batholith. Previously, Tempelman-Kluit (1972) and Gordey (1990) included the rocks here assigned to Unit 4 in the Anvil Range Group.

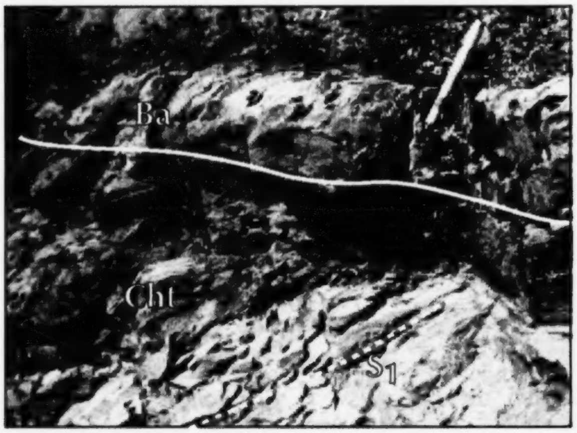

Figure 11. Lower barite horizon in Unit 4 - Earn Group. Ba is barite, and cht is chert. Foliation (S_1) is shown by the dashed line.

UNIT 5 - MOUNT CHRISTIE FORMATION

Pale green, noncalcareous, bedded, phyllitic cherts constitute Unit 5. The chert beds are 5 to 15 cm thick and alternate with pale green argillite interbeds (Fig. 12). Unit 5 typically weathers orange brown; locally it contains an intense dark brown manganese oxide surface staining.

The pale cherts contain minor intervals of dark grey to black chert and argillite up to 15 m thick. Locally, the upper portion of Unit 5 contains thin to thick interbeds of maroon to dark red argillite and lesser chert. The proportion and thickness of these reddish interbeds changes rapidly along strike; in the NW area the red beds are not present and in the SE area they are slightly over 60 m thick.

Both upper and lower contacts are conformable. The upper contact is transitional with interbedding of cherts and the overlying volcanic rocks of Unit 6. The lower contact is also transitional with local interbedding of dark grey to black chert with pale green chert over a 20 m interval. Unit 5 is approximately 420 m thick.

Tempelman-Kluit (1972, 1979) collected latest Pennsylvanian or earliest Permian fusulinids and Pennsylvanian conodonts from a thin limestone bed approximately 60 m below the upper contact of Unit 5 in the SE Rose Mountain area. On the northeast side of Anvil Batholith, the rocks correlative with Unit 5 are described by Gordey and Anderson (1993) as thin-bedded, light grey green to black chert of the middle Pennsylvanian Mount Christie Formation. The Mount Christie Formation does not contain red or maroon cherts and argillites, but is equivalent to a green and red slate with minor chert unit in Dawson map area (Unit 14 of Tempelman-Kluit (1970). Previously Tempelman-Kluit (1972) and Gordey (1990) included the rocks here assigned to Unit 5 in the Anvil Range Group. On the basis of age and lithologic similarity, Unit 5 is herein correlated with Mount Christie Formation.

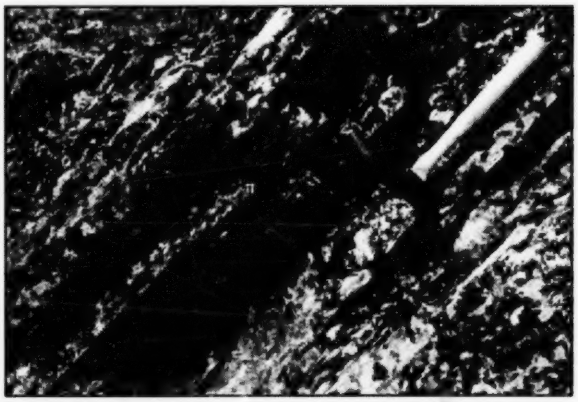

Figure 12. Bedded, pale cream phyllitic chert of Unit 5 - Mount Christie Formation.

UNIT 6 - ANVIL RANGE GROUP BASALT

Dark green, massive, aphanitic basalts which weather to a dark reddish brown characterize Unit 6 in the Rose Mountain area. Breccia textures with subangular to rounded clasts of basalt in a dark green to reddish green, aphanitic matrix are locally visible (Fig. 13). Patchy epidote alteration locally gives the basalt a medium green colouration. Foliation within the basalt is rarely visible.

The lower contact is conformable with some transitional interbedding of basalt with chert. The upper contact of Unit 6 was not observed. Tempelman-Kluit (1972, 1979) included the rocks here assigned to Unit 6 as part of the Anvil Range Group and considered them to be Permian. Exposures of this unit occur along a southeast trend with a strike length of at least 50 km (Gordey and Irwin, 1987).

Rocks equivalent to Unit 6 have not been observed northeast of Anvil Batholith, nor have they been recognized elsewhere in North American miogeocline stratigraphy (Abbott et al., 1986). Tempelman-Kluit (1979) correlated Unit 6 with basalts and ultramafic rocks of Anvil allochthon, a major obducted oceanic ophiolite assemblage, on the basis of age and lithologic similarity. Other regions correlated with Anvil allochthon and therefore consistent with Unit 6 are in Campbell Range belt (cf. Plint and Gordon, 1997) and Sylvester allochthon (cf. Nelson and Bradford, 1993).

SUMMARY AND DISCUSSION

Units 1 through 6 form a consistent, mappable succession over 10 km in strike length and approximately 2000 m in structural thickness. The units range in age from Ordovician to Permian. Within this succession units 3 through 6 have transitional contacts indicating they also form a stratigraphic succession without any internal structural discontinuity. The contact between Unit 3 and Unit 2 is not exposed; its structural nature is unknown.

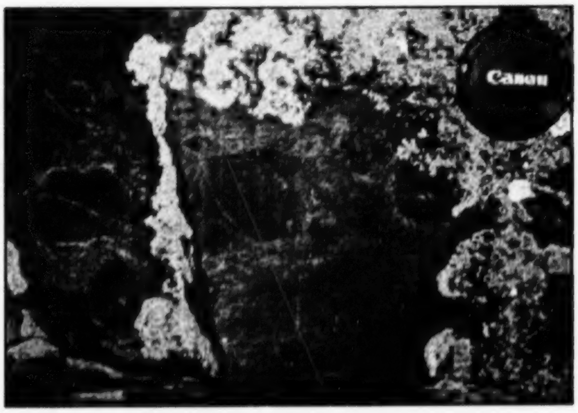

Figure 13*. Auto-brecciated metabasalt of Unit 6 – Anvil Range Group.*

Units 1 and 2 have been correlated with Lower Paleozoic North American regional miogeocline stratigraphic units. Units 4 and 5 are also confidently correlated with Earn Group and Mount Christie Formation of the North American miogeocline, respectively. The lithologic similarity of these units to ancestral North American regional stratigraphy suggests that the entire Rose Mountain succession from Units 1 through 6 should be considered as a concordant package of units deposited on the ancient North American margin.

Unit 3 is inconsistent with correlation to regional stratigraphic units in both the North America miogeocline and Yukon-Tanana Terrane. It occurs above the Ordovician to Silurian Duo Lake Formation and below the Devonian to Mississippian Earn Group. If the Rose Mountain succession is intact, Unit 3 should be considered Silurian to Devonian in age. It would possibly correlate with bioturbated, pale grey siltstones of the Steel Formation (Gordey and Anderson, 1993). Alternatively it would possibly correlate with Earn Group strata with the source provenance for the coarse clastics and maroon metasediments within Unit 3 being Hyland Group. Because of the intimate intermixing of pale and dark grey lithologies at the upper contact of Unit 3, and the occurrence of typical Earn Group coarse clastic lithologies within Unit 3, I would favour the latter interpretation.

Units 3 through 6 have previously been interpreted as allochthonous Anvil assemblage thrust northeastward over the Road River Group (Unit 2) and Menzie Creek formation (Unit 1) of North American affinity (Gordey, 1990). If the Rose Mountain succession is entirely North American stratigraphy, the structural necessity for a large displacement thrust fault is removed. The allochthonous Anvil terrane is therefore not present atop North American terrane. Similarly, in the Finlayson area, about 190 km to the southeast, Murphy (1998) suggested that allochthonous Anvil assemblage may actually represent intrusive sills within Yukon-Tanana Terrane. Further work is needed to determine the true nature and provence of the Anvil assemblage.

Unit 6, with no correlative unit within ancestral North American stratigraphy, is most similar in age and lithology to mafic volcanics in Campbell Range belt and in the Sylvester allochthon. Unit 5 also appears similar to rocks in Campbell Range belt and in Sylvester allochthon. In these locations, the correlative units are mapped and interpreted as the suspect Slide Mountain Terrane. The dual correlative nature of Units 5 and 6 in Rose Mountain area suggests the possibility that by Pennsylvanian time, North America and Slide Mountain basements were contiguous so that subsequent units were deposited as an overlap assemblage.

ACKNOWLEDGEMENTS

Jason Adams provided assistance with the 1998 field work. Discussions of the Rose Mountain geology with Gregg Jilson (Access Consulting Group), Steve Gordey (Geological Survey of Canada), Don Murphy (Yukon Geology Program) and Grant Abbott (Yukon Geology Program) were helpful. This paper was reviewed by Grant Abbott and Charlie Roots.

REFERENCES

Abbott, J.G., Gordey, S.P. and Tempelman-Kluit, D.J., 1986. Setting of stratiform, sediment-hosted lead-zinc deposits in Yukon and northeastern British Columbia. *In:* Mineral Deposits of Northern Cordillera, J.A. Morin (ed.), Canadian Institute of Mining and Metallurgy, Special Volume 37, p. 1-18.

Bond, J.D., 1999 (this volume). The Quaternary history and till geochemistry of the Anvil District, east-central Yukon. *In:* Yukon Exploration and Geology 1998, C.F. Roots and D.S. Emond (eds.), Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 105-116.

Cecile, M.P., 1982. The lower Paleozoic Misty Creek Embayment, Selwyn Basin, Yukon and Northwest Territories. Geological Survey of Canada, Bulletin 335, 78 p.

Coney, P.J., Jones, D.L. and Monger, J.W.H., 1980. Cordilleran suspect terranes. Nature, vol. 288, p. 329-333.

Franzen, J.P., 1978. Geological report URN Claim Group. Unpublished Assessment Report #090345, Mineral Resources Directorate, Yukon, Indian and Northern Affairs Canada.

Goodfellow, W.D., Cecile, M.P. and Leybourne, M.I., 1995. Geochemistry, petrogenesis, and tectonic setting of lower Paleozoic alkalic and potassic volcanic rocks, Northern Canadian Cordilleran miogeocline. Canadian Journal of Earth Sciences, vol. 32, p. 1236-1254.

Gordey, S.P., 1983. Thrust faults in the Anvil Range and a new look at the Anvil Range Group, south-central Yukon Territory. Geological Survey of Canada, Paper 83-1A, p. 225-227.

Gordey, S.P., 1990. Geology of Mt. Atherton (105K/4), Rose Mountain (105K/5), and Mount Mye (105K/6) map areas, Yukon Territory. Geological Survey of Canada, Open File 2250 (1:50 000 scale).

Gordey, S.P., Abbott, J.G. and Orchard, M.J., 1982. Devono-Mississippian (Earn Group) and younger strata in east-central Yukon. Geological Survey of Canada, Paper 82-1B, p. 93-100.

Gordey, S.P. and Anderson, R.G., 1993. Evolution of the northern cordilleran miogeocline, Nahanni map area (105I), Yukon and Northwest Territories. Geological Survey of Canada, Memoir 428, 214 p.

Gordey, S.P. and Irwin, S.E.B., 1987. Geology, Sheldon Lake and Tay River map areas, Yukon Territory. Geological Survey of Canada, Map 19-1987 (3 sheets; 1:250 000 scale).

Jennings, D.S. and Jilson, G.A., 1986. Geology and sulfide deposits of Anvil Range, Yukon Territory. *In:* Mineral Deposits of Northern Cordillera, J.A. Morin (ed.), Canadian Institute of Mining and Metallurgy, Special Volume 37, p. 319-361.

Mortensen, J.K., 1992. Pre-mid-Mesozoic tectonic evolution of the Yukon-Tanana Terrane, Yukon and Alaska. Tectonics, vol. 11, p. 836-853.

Mortensen, J.K. and Jilson, G.A., 1985. Evolution of the Yukon-Tanana Terrane: evidence from southeastern Yukon Territory. Geology, vol. 13, p. 806-810.

Murphy, D.C., 1998. Stratigraphic framework for syngenetic mineral occurrences, Yukon-Tanana Terrane south of Finlayson Lake: a progress report. *In:* Yukon Exploration and Geology 1997, Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 51-58.

Nelson, J.L. and Bradford, J.A., 1993. Geology of the Midway-Cassiar area, northern British Columbia (104O, 104P). British Columbia Ministry of Energy, Mines and Petroleum Resources, Bulletin 83, 94 p.

Pigage, L.C., 1990. Field guide Anvil Pb-Zn-Ag District, Yukon Territory, Canada. *In:* Mineral deposits of the northern Canadian Cordillera, Yukon-northeastern British Columbia (Field Trip 14). J.G. Abbott and R.J.W. Turner (eds.), Geological Survey of Canada, Open File 2169, p. 283-308.

Pigage, L.C. and Anderson, R.G., 1985. The Anvil plutonic suite, Faro, Yukon Territory. Canadian Journal of Earth Sciences, vol. 22, p. 1204-1216.

Plint, H.E. and Gordon, T.M., 1997. The Slide Mountain Terrane and the structural evolution of the Finlayson Lake fault zone, southeastern Yukon. Canadian Journal of Earth Sciences, vol. 34, p. 105-126.

Read, W.S., 1982. Report on URN Barite property. Unpublished assessment report 091369, Mineral Resources Directorate, Yukon, Indian and Northern Affairs Canada, Whitehorse.

Roddick, J.A. and Green, L.H., 1961. Tay River, Yukon Territory. Geological Survey of Canada, Map 13-1961 (1:253 440 scale).

Smith, J.M. and Erdmer, P., 1990. The Anvil aureole, an atypical mid-Cretaceous culmination in the northern Canadian Cordillera. Canadian Journal of Earth Sciences, vol. 27, p. 344-356.

Tempelman-Kluit, D.J., 1970. Stratigraphy and structure of the "Keno Hill Quartzite" in Tombstone River – upper Klondike River map-areas, Yukon Territory. Geological Survey of Canada, Bulletin 180, 102 p.

Tempelman-Kluit, D.J., 1972. Geology and origin of the Faro, Vangorda, and Swim concordant zinc-lead deposits, central Yukon Territory. Geological Survey of Canada, Bulletin 208, 73 p.

Tempelman-Kluit, D.J., 1979. Transported cataclasite, ophiolite and granodiorite in Yukon: Evidence of arc-continent collision. Geological Survey of Canada, Paper 79-14, 27 p.

Wheeler, J.O. and McFeely, P., 1987. Revised tectonic assemblage map of the Canadian Cordillera and adjacent parts of the United States of America. Geological Survey of Canada, Open File 1565.

Yukon Minfile. Exploration and Geological Services Division, Indian and Northern Affairs Canada. Also available from Hyperborean Productions, Whitehorse, Yukon.

The Quaternary history and till geochemistry of the Anvil District, east-central Yukon

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ABSTRACT

Till geochemistry and glacial geology have rarely been integrated into Yukon mineral exploration. In the Anvil District, thick glacial deposits have consistently hampered exploration. From the initial (massive sulphide) discovery in Vangorda Creek, twenty years elapsed before the Grum deposit was discovered only two kilometres to the northwest. This work examines the utility of till geochemistry as a method to trace mineralized soil/till samples back to their source rocks in the Anvil District. The Anvil District was last glaciated during the McConnell glaciation, which had a significant impact on the local terrain. The relatively swift-flowing Cordilleran ice sheet deposited thick sequences of till in low-lying areas and eroded southeast-facing slopes and hill summits in the Swim Basin and Vangorda Plateau. This type of glacial history is conducive for till geochemical exploration. A 12 km^2 till grid was sampled northwest of the Faro deposit to map the glacial dispersion train. The till geochemistry on the -230 mesh fraction (silt and clay) indicated a broad dispersion plume for lead, zinc, and copper, extending more than 5 km west of the Faro Pb/Zn deposit. A section of the dispersion train may have a palimpsest origin. The soil geochemistry on the -80 mesh fraction, from 1964 data, indicated a much narrower dispersion plume extending directly from the Faro deposit. Till geochemistry, particularly on the fine fraction, has applications to similar drift-covered terrain, such as the Finlayson Lake massive sulphide district to the southeast.

RÉSUMÉ

La géochimie du till et la géologie des formations glaciaires ont été considérablement sous-utilisées en prospection minière au Yukon. Dans le district d'Anvil, d'épais dépôts glaciaires ont nui de manière persistante à l'exploration. Depuis l'époque de la découverte initiale au ruisseau Vangorda, il aura fallu 20 ans pour découvrir le gisement Grum pourtant situé à seulement deux kilomètres au nord-ouest. Dans cette étude, on examine l'utilité de la géochimie du till comme méthode pour retracer la source des échantillons de sol/till minéralisés jusqu'à la roche mère dont ils proviennent dans le district d'Anvil. La glaciation de McConnell est la dernière qui a touché le district d'Anvil et elle a eu une incidence importante dans ce secteur. L'inlandsis de la Cordillère, dont l'écoulement était relativement rapide, a déposé d'épaisses séquences de till dans les étendues basses et a érodé les versants face au sud-ouest ainsi que les sommets des collines du bassin Swim et du plateau Vangorda. Ce type d'histoire glaciaire se prête bien à la prospection basée sur la géochimie du till. Le till a été échantillonné sur un quadrillage s'étendant sur 12 km^2 au nord-ouest du gisement Faro dans le but de cartographier la dispersion par la glace des sédiments minéralisés. La géochimie de la fraction du till acceptée au tamis de 230 mesh (limon et argile) révèle pour le plomb, le zinc et le cuivre un large panache de dispersion s'étendant jusqu'à plus de 5 km à l'ouest du gisement Faro de Pb/Zn. Un segment de la traînée de dispersion peut avoir comme origine une structure résiduelle. La géochimie de la fraction du sol acceptée au tamis de 80 mesh révèle, d'après des données de 1964, un panache de dispersion beaucoup plus étroit directement derrière le gisement Faro. La géochimie du till, et particulièrement de la fraction fine, a des applications dans les terrains analogues recouverts de sédiments glaciaires comme le district à sulfures massifs de Finlayson au sud-est.

INTRODUCTION

Quaternary geology and till geochemistry research, in conjunction with bedrock mapping (see Pigage, this volume) and lithogeochemistry, has been initiated as part of an interdisciplinary research program in the Anvil District, east-central Yukon. Thick glacial deposits have consistently hampered exploration in the Anvil District. From the time of the initial Pb/Zn discovery made in Vangorda Creek in 1953, it took an additional twenty years before the Grum deposit was discovered only two kilometres to the northwest.

The study discussed in this paper examines the utility of till geochemistry as a method to trace dispersed mineralized sediment in the Anvil District. Research focussed on Quaternary history, surficial geological mapping, glacial dispersion mapping, stratigraphic and regional till geochemistry, as well as expanding on results of the drift exploration case study completed at the Faro Pb/Zn deposit.

BACKGROUND

The use of till geochemistry, or boulder tracing, as a method of prospecting in glaciated terrain has long been recognised. In Finland, as early as 1740, it had been noted that erratic blocks could be traced to their source and may have applications to the location of ore deposits (Shilts, 1976). It was not until the early twentieth century however, that drift prospecting became recognized as a valuable method in the exploration industry. Canadian research into drift exploration has largely focussed in the Canadian Shield, and now more recently, to central British Columbia, Vancouver Island, and southern British Columbia by the British Columbia Geological Survey. Few studies have addressed the applicability of this technique in the Northern Cordillera where permafrost provides an additional hindrance to preliminary surveys.

A case study of this technique in the Anvil District aims to provide a background methodology for future reference by exploration programs in drift-covered terrain. This may prove particularly useful in the Finlayson Lake base metal district further to the southeast; this area has high mineral potential with a large portion of the area blanketed by glacial drift.

PHYSIOGRAPHY, DRAINAGE AND GEOLOGY

PHYSIOGRAPHY

The Anvil District is located in the east-central Yukon and is part of a northwest trending belt located between the northeastern flank of the Anvil Range and Tintina Trench (Figs. 1 and 2).

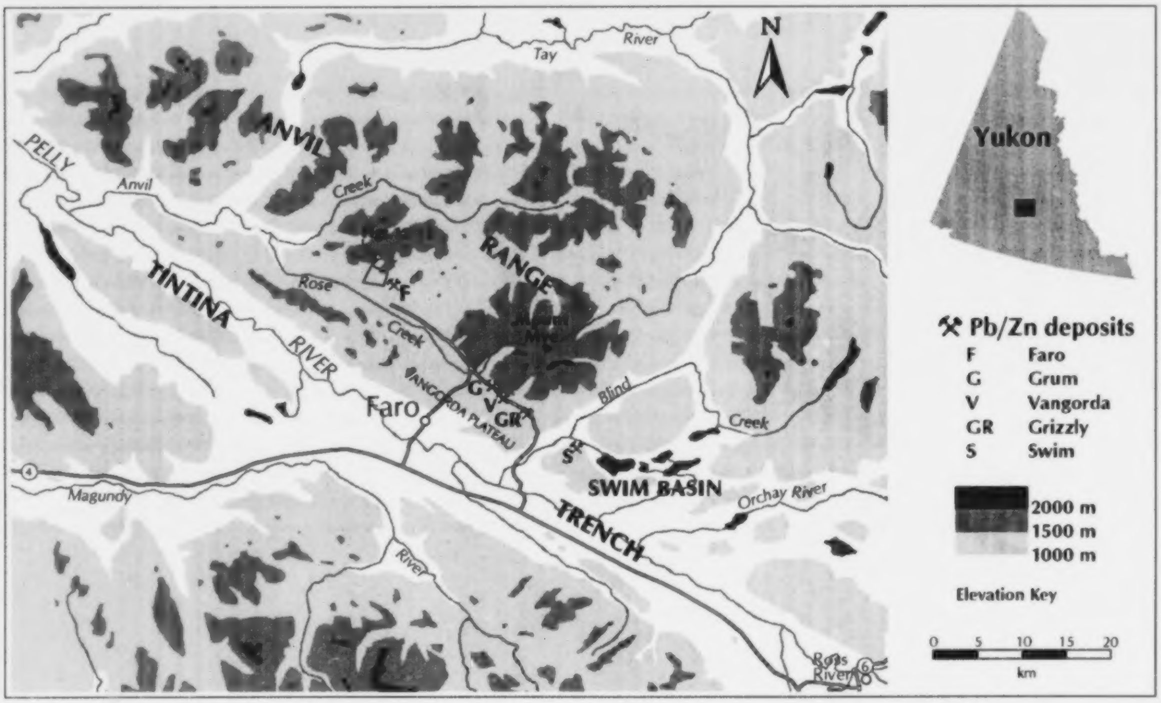

Figure 1. *Location and physiography of the Anvil District, east-central Yukon.*

Vangorda Plateau, a rolling upland averaging 1219 m (4000 ft), is bounded by the Blind Creek valley and Tie faults, and separates the Mount Mye upland from Tintina Trench. Swim Basin is the structural and physiographic continuation of Vangorda Plateau to the southeast. Anvil Range consists of a series of massifs reaching 1981 m (6500 ft) that are separated by glacial valleys averaging 1341 m (4400 ft). Cirque valleys radiate from all the uplands in the Anvil Range.

DRAINAGE

The regional drainage of the Anvil District is into the Pelly River (Fig. 1). Streams flowing north off the Anvil Range flow into the Tay River prior to entering the Pelly River and streams draining southeast and southwest feed into the Pelly River either directly, via Blind Creek, or via Anvil Creek.

GEOLOGY

The Anvil District is part of the Selwyn Basin, a deep-water sedimentary basin that formed along the ancient North American continental margin during the late Proterozoic and early Paleozoic (Gabrielse, 1967). The Anvil District is located on the outboard edge of the basin and is dominated by successions of basin-filling sediments. The stratigraphic sequence comprising the Anvil District extends from latest Precambrian to Ordovician and can be divided into three formations: Mount Mye (oldest), Vangorda, and Menzie Creek (youngest; Jennings and Jilson, 1986). Mount Mye formation is a deep marine sequence dominated by non-calcareous phyllite and schist with lesser marble and calc-silicate lenses, carbonaceous schist, minor psammitic schist and metabasite. Vangorda formation is also a deep marine sequence, dominated by calcareous phyllite and schist with lesser marble and calc-silicate lenses, carbonaceous schist, minor psammitic schist and metabasite. Menzie Creek formation is a 1 km thick sequence of metavolcanic rocks deposited through episodic extensional tectonism on the continental margin and is gradational with the Vangorda formation. The Anvil District Zn/Pb/Ag stratiform pyritic massive sulphide deposits occur within a 150 m interval in the pre-Ordovician strata at the contact between Mount Mye and Vangorda formations. The Anvil District hosts five ore deposits along a northwest-southeast curvilinear trend: Faro, Grum, Vangorda, Grizzly, and Swim (Fig. 1).

The mid-Cretaceous Anvil Range plutonic suite intruded the Selwyn Basin stratigraphy in response to collision of Yukon-Tanana suspect terrane with ancient North America. Movement along the Tintina Fault began in the late Cretaceous and continued into the early Tertiary (Pigage, 1990).

METHODOLOGY

Surficial geological mapping was completed at 1:25 000 scale and provided the baseline information for the glacial history interpretation of the Anvil District. Quaternary sections were logged in the open pits on Vangorda Plateau and in Rose Creek valley, in addition to natural and road-cut sections in Blind Creek valley. The principal till geochemical case study for the 1998 season was completed northwest of Faro deposit in Rose Creek valley. In total, 140 samples were gathered from a 3 km by 4 km grid. Samples were spaced every 200 m and line spacing progressed from 200 m to 500 m over 13 lines total. Till samples were obtained by hand digging with a pick and shovel to a depth averaging 71 cm or sufficiently deep to penetrate post-glacial soil development and any possible air-born contamination in the soil from the nearby mining activity (Fig. 3). Where possible, compact basal till or colluviated till was sampled. On the lower slopes of the grid, alluvial organic silt

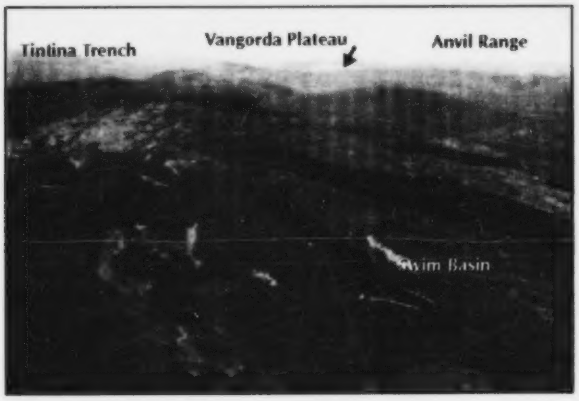

Figure 2. *An oblique air photograph of the Anvil Disrict physiography. View is to the west. Note the Grum and Vangorda mines in the middle background (see arrow).*

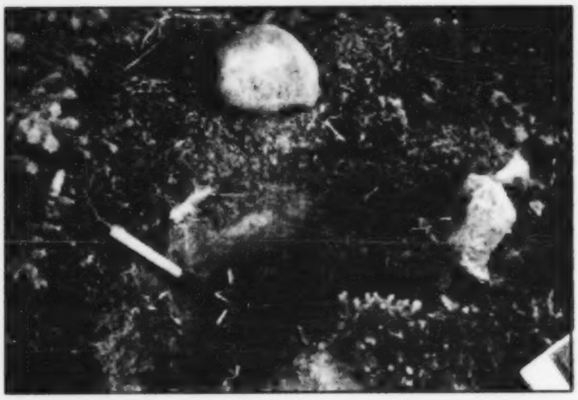

Figure 3. *Sample taken in a compact basal till on the Faro grid. The White River ash is visible at the surface next to the shovel. Soil development at locations such as this is limited to the upper 25 cm. Pit depth is 65 cm.*

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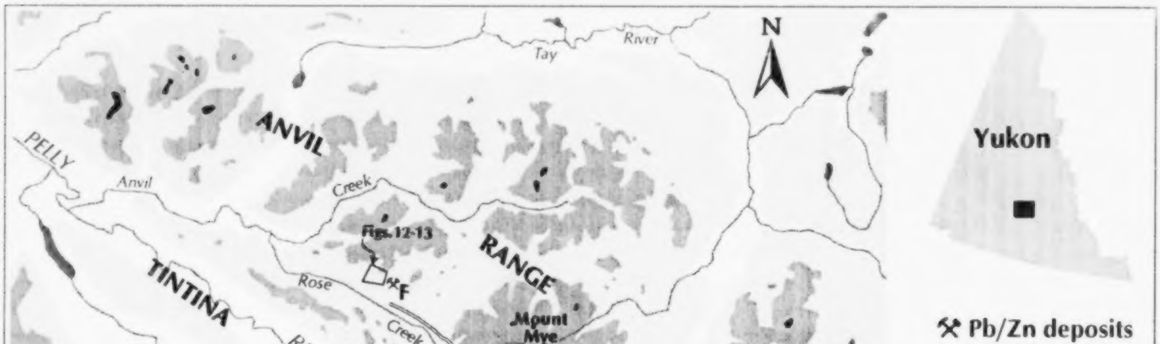
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TRENCH
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6
Pb/Zn deposits
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G Grum
V Vangorda
GR Grizzly
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Figure 1. Location and physiography of the Anvil District, east-central Yukon.

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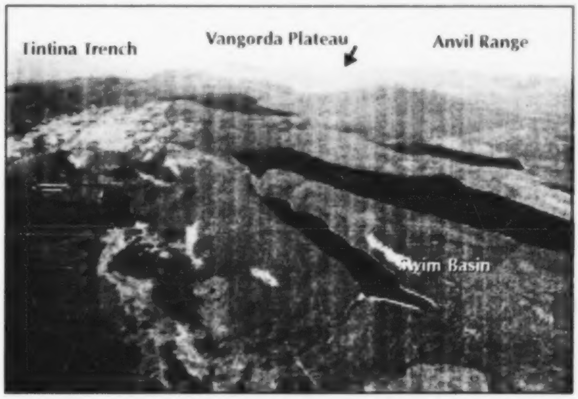

Figure 2. *An oblique air photograph of the Anvil Disrict physiography. View is to the west. Note the Grum and Vangorda mines in the middle background (see arrow).*

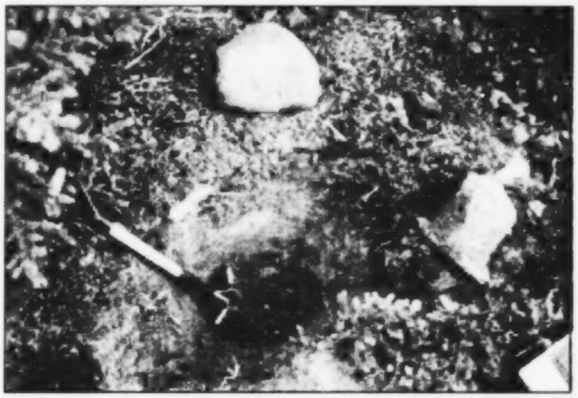

Figure 3. *Sample taken in a compact basal till on the Faro grid. The White River ash is visible at the surface next to the shovel. Soil development at locations such as this is limited to the upper 25 cm. Pit depth is 65 cm.*

containing sporadic permafrost was encountered; this often required digging more than one pit to reach depths sufficient to uncover at least a lens of colluviated till. This sampling method would be inhibited by widespread permafrost, especially where till is not part of the active layer. Samples averaging 10 kg were bagged, and later split and sieved to separate the silt/clay fraction (-230 mesh) for standard 32 element ICP-AES and a fire assay for gold at Chemex Labs in Vancouver, B.C. According to Shilts (1984), analysis of the −230 mesh fraction is advantageous for examining sulphide concentrations in till. Post-glacial weathering of sulphide minerals occurs readily and simultaneously causes metal enrichment in the clay-sized fraction. Clay minerals act as scavengers by retaining the metal fraction; thus the samples with a larger percentage of clay would give higher metal values, especially where mineralization occurs locally (Nikkarinen et al., 1983).

Till was sampled from Quaternary exposures in the Faro, Grum, and Vangorda open-pits to evaluate geochemical changes with depth. Regional till sampling was carried out on the southeastern end of the Vangorda Plateau, Blind Creek valley, and in the Swim Basin to assess the potential for a buried massive sulphide deposit and to better quantify the background geochemical values for the district. A small geochemical grid was sampled west of the Swim deposit. In total, 227 drift samples were obtained in the Anvil District in 1998.

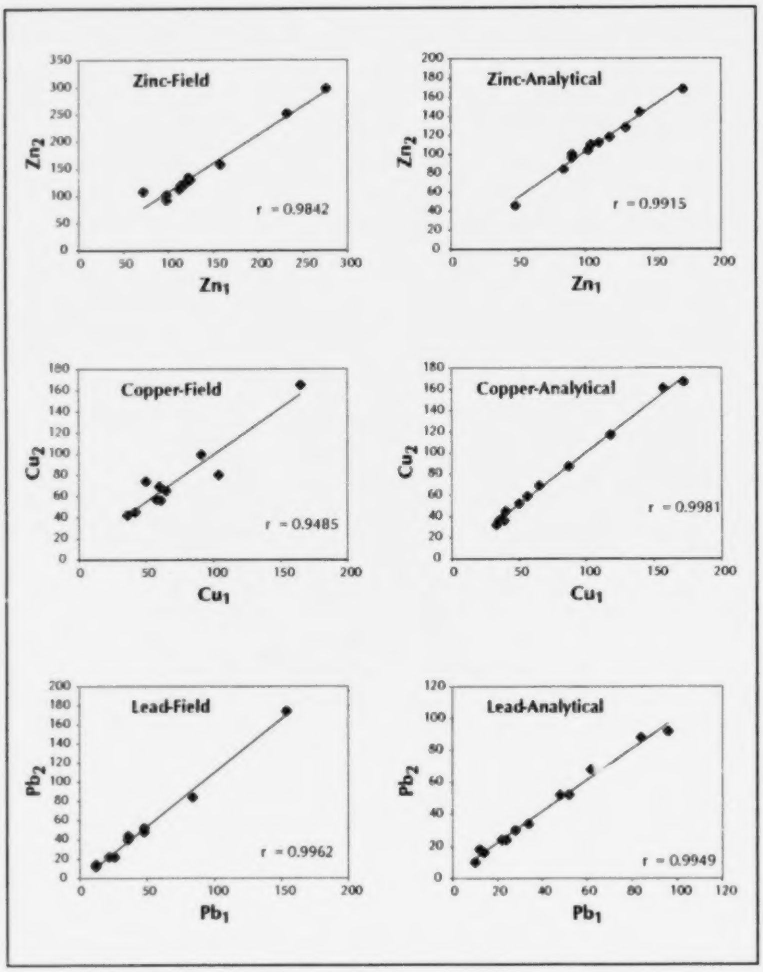

Figure 4. *Bivariate scatter plots for field and analytical duplicates showing zinc, copper and lead in ppm's. The r-values (> 0.90) indicate a good correlation between the duplicate pairs and no major discrepancies for the field and analytical methods.*

Quality control was maintained by submitting field and analytical duplicates to check for problems in field sampling and analytical techniques. A field and analytical duplicate was submitted in every set of 20 samples. CANMET control standards were submitted in every 30 samples taken.

Field and analytical duplicates are presented for zinc, copper, and lead. The bivariate scatter plots show good reproducibility (r > 0.90) for both field and analytical duplicates (Fig. 4). Higher r-values were obtained for the analytical duplicates than the field duplicates for both copper and zinc. This suggests that field duplicates have higher geochemicial variability than analytical duplicates for copper and zinc in this data set.

QUATERNARY HISTORY

The Yukon was last glaciated during the late Wisconsinan McConnell glaciation approximately 20,000 years ago (20 Ka). The McConnell glaciation represents the most recent glaciation in a glacial/interglacial cycle that dates to the beginning of the Quaternary period approximately 2.5 million years ago (2.5 Ma). The earliest glaciations (pre-Reid), at the onset of the Quaternary period or early Pleistocene, were the most extensive and are largely responsible for the current regional drainage configuration in the Yukon (Fig. 5). More recent glaciations such as the Reid (middle Pleistocene) and McConnell (late Pleistocene) have well defined limits within the pre-Reid glacial limits (Bond, 1997). In the Anvil District,

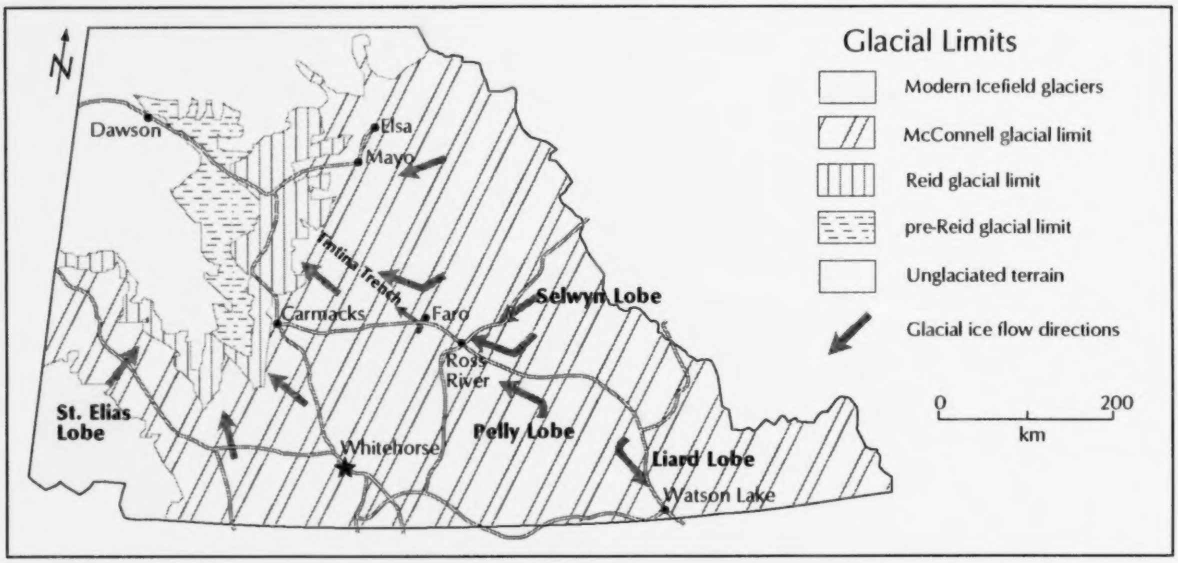
N
Glacial Limits
Modern Icefield glaciers
McConnell glacial limit
Reid glacial limit
pre-Reid glacial limit
Unglaciated terrain
Glacial ice flow directions
0
200
km
Dawson
Elsa
Mayo
Tintina Trench
Carmacks
Faro
Selwyn Lobe
Ross River
St. Elias Lobe
Whitehorse
Pelly Lobe
Liard Lobe
Watson Lake

Figure 5. *Cordilleran glacial limits and flow lines in southern Yukon with position of regional ice lobes (Bostock, 1966; Jackson, 1994).*

record of the older glaciations was eroded or buried during the last glaciation.

McConnell ice originated from regional accumulation zones in the Selwyn, Pelly and St. Elias Mountains. The Anvil District was dominantly glaciated by ice from the Selwyn and Pelly Mountains, and by local glaciers from the Anvil Range. The Selwyn and Pelly lobes, in the vicinity of Ross River and Faro, were funneled into Tintina Trench and followed the topographic lineament northwest into central Yukon (Fig. 5). Streamlined landforms developed proximal to the Tintina Trench under the relatively rapid ice flow conditions (Fig. 6). Ice flow in the Swim Basin, according to aligned landforms, was largely from east to west, becoming more northwesterly upon intersecting Blind Creek valley and Vangorda Plateau. Till fabric data from exposures on Vangorda plateau show some ice-flow variability which likely reflects a directional change from Mount Mye alpine ice merging with the main Cordilleran ice sheet. Ice flow continued to the northwest into Rose Creek valley where it became valley-confined. Nunataks were present in the Anvil Range during the last glaciation (Jackson, 1994).

McConnell deglaciation, according to Jackson (1987; 1994), occurred rapidly when the equilibrium line rose significantly above the 1830 m elevation. This resulted in the wholesale starvation of the ice sheet. A subsequent re-advance by the Cordilleran ice sheet has been documented in many areas of central Yukon and appears to be consistent with the glacial history of the Anvil District. Lateral moraines and meltwater channels of the Cordilleran ice sheet extend into local alpine valleys, and flights of kame terraces in the alpine valley bottoms indicate an invading ice front from outside the upland. A glacial lake formed in the Tintina Trench at the end of the glaciation and is informally termed Glacial Lake Pelly.

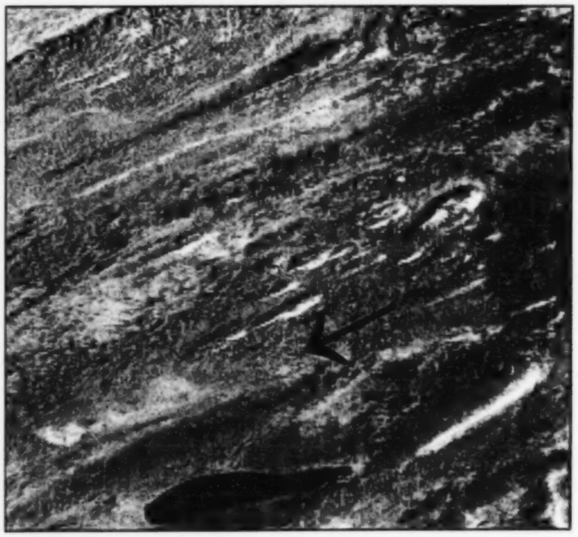

Figure 6. *Aerial photograph of streamlined terrain in the Swim Basin. The ice-flow direction, indicated by the arrow symbol, is to the west.*

The onset of the McConnell glaciation occurred after 26,350 ± 280 BP (Jackson, 1991; TO-393) according to a radiocarbon date on a bone fragment of *Bison priscus* along the Ketza River. According to Ward (1989), deglaciation of the Pelly River was complete by 12,590 ± 540 BP (TO-931).

SURFICIAL GEOLOGY

The surficial geology of the Anvil District is controlled by the three physiographic divisions: Anvil Range, Vangorda Plateau/Swim Basin, and Tintina Trench. Anvil Range is covered by colluvium, with exposed rock above 1768 m (5800 ft) and at lower elevations on north- and west-facing slopes where nivation processes are common. Erratics and meltwater channels were mapped to at least 1707 m (5600 ft), however no significant glacial deposits were noted at this elevation (Fig. 7). The flanks of the upland have increased glacial sediment cover below 1463 m (4800 ft; Fig. 8). Till and deltaic deposits were mapped in the Mount Mye alpine valleys to 1554 m (5100 ft). Glacial drift in the alpine valleys of Mount Mye, and possibly in other neighbouring alpine valleys, consists of combined sediment from alpine glaciers and the Cordilleran ice sheet which invaded the alpine uplands at the end of the McConnell glaciation. Sporadic rock glaciers were mapped in the Anvil Range on north-facing slopes.

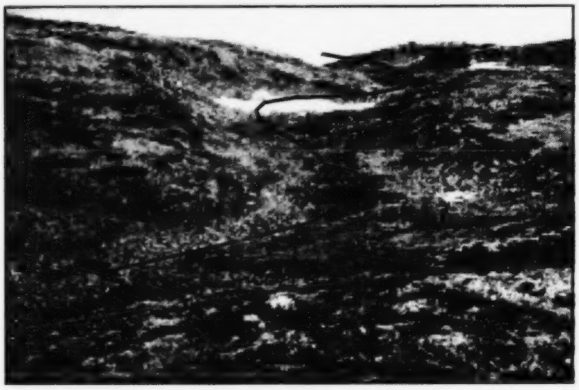

Figure 7. *A meltwater channel formed by outwash emitted off the Selwyn ice lobe. The channel cuts across a plateau at 1676 m (5500 ft) on Mount Mye. Landforms such as this are common on the flanks of the Anvil Range between the elevations of 1310 –1768 m (4300-5800 ft).*

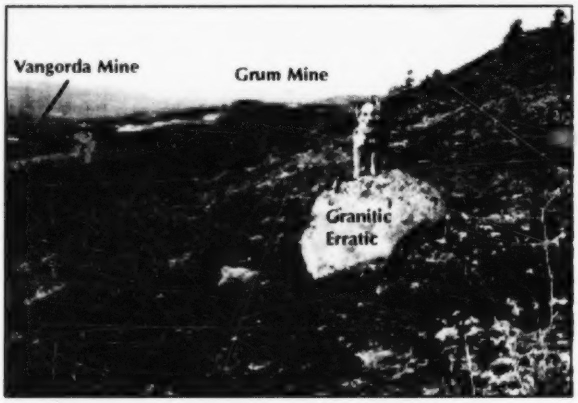

Figure 8. *Erratics are common in the Anvil District. Here a Cretaceous granitic boulder was found lying on rocks of the lower Cambrian Mount Mye formation at 1433 m (4700 ft). Vangorda Plateau and two of the Anvil District mines are visible in the background. View is to the west.*

Vangorda Plateau and Swim Basin are draped with till blankets and minor till veneers (Fig. 9). Glacial outwash deposits occupy low channels cutting the rolling upland surface. Till veneers and colluviated till veneers are common on south- and southeast-facing slopes which were exposed to glacial erosion by the northwesterly flowing ice sheet. Crag-and-tail landforms were also noted at the tops of southeast-facing slopes from subglacial erosion of relatively resistant bedrock (Fig. 10). These landforms develop when a glacier intersects a resistant bedrock "crag" and leaves a pressure void in the down-ice direction. In the pressure void, or "tail," sedimentation occurs and/or a ridge of less resistant bedrock is preserved. Crag-and-tails are useful indicators of ice-flow direction.

Thick glaciolacustrine beds were deposited in Tintina Trench at the end of the McConnell glaciation (Fig. 11). Holocene erosion of the glaciolacustrine deposits by the Pelly River has left remnant deposits lining the Tintina Trench/Pelly River valley. Complexes of hummocky glacial meltout surfaces, particularly common between Faro and Blind Creek valley, also line Tintina

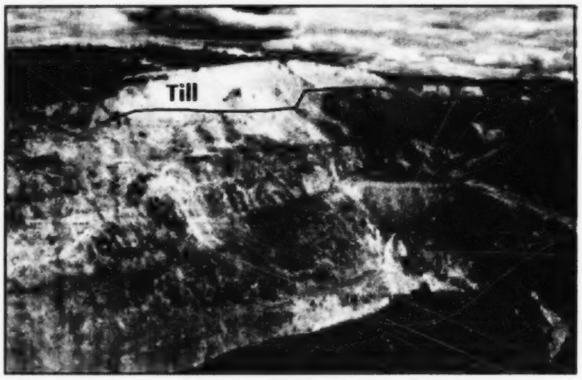

Figure 9. *Vangorda mine looking to the southeast. A blanket of till is visible on the pit wall in the background. The till depth varies from 1 m to 50 m.*

Trench. Meltout deposits consist of mixed glaciofluvial gravel, resedimented till, and sporadic in-situ glacial ice lenses.

IMPLICATIONS OF GLACIAL HISTORY ON EXPLORATION IN THE ANVIL DISTRICT

Thick glacial sediment sequences across the Vangorda Plateau and Swim Basin has hampered exploration in the Anvil District. Excessive glacial deposition is likely a factor of the district's relatively low-rolling physiography. The rapid ice flow through the area had high erosional capabilities which increased the sediment being transported by the glacier and ultimately deposited by the glacier. Areas of thin drift (till veneers < 1 m) or exposed bedrock are found on or near the crest of southeast-facing slopes and on hill summits in Swim Basin and on Vangorda Plateau. Thick glacial deposits, in contrast, accumulated on the lee-side of hill slopes, in localized basins and on the lower flanks of southeast-facing slopes. Surface samples from an area of thick till cover generally contain bedrock fragments which are further removed, as opposed to a shallow till which predominantly reflects local bedrock sources. With this in mind, soil assays can be relatively calibrated according to the topographic setting and the glacial sediments from which they were collected.

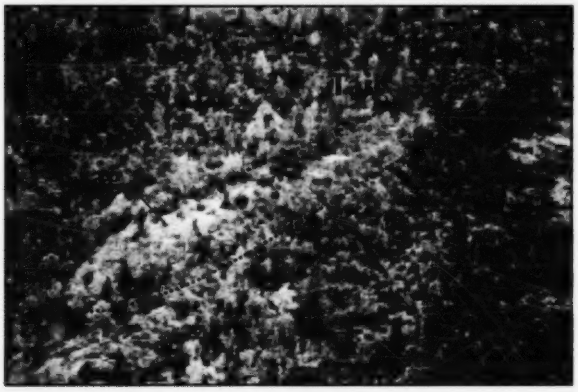

Figure 10. *A crag-and-tail landform on the Vangorda Plateau. Direction of ice flow was from the lower left to the upper right or to the west northwest. This landform is approximately 175 m long.*

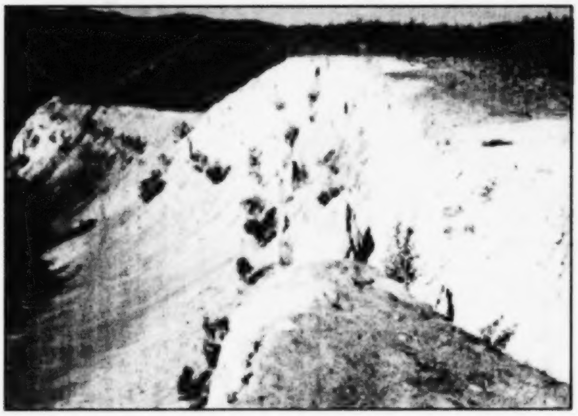

Figure 11. *Glaciolacustrine silt in the Pelly River valley/Tintina Trench. The silt exposure is more than 100 m high.*

The late McConnell re-advance by the Cordilleran ice sheet could have implications regarding the origin of surface till in alpine valleys. Due to the absence of local alpine glaciers at the time of the readvance, alpine valleys were inundated by Cordilleran ice, therefore allowing for the deposition of foreign sediments. This late glacial history could play an important role in determining the origin of soil parent material and potential dispersion trends in alpine valleys in the Anvil District.

FARO DEPOSIT CASE STUDY

The underlying principal of till geochemistry is based on the probability of detecting a dispersion train which may have a surface area hundreds of times larger than its original bedrock source. The Faro deposit case study was completed to determine the size and magnitude of glacial dispersion from a known source, using a sampling technique designed to accentuate subtle enrichment related to sulphide deposits. This technique may be valuable in regional exploration for similar deposits in glaciated terrain to the southeast of the Anvil District. The sampling program was modeled after similar studies by the British Columbia Geological Survey in southern and central B.C. (Levson et al., 1994a, 1994b, and 1994c; Giles and Kerr, 1993; Bobrowsky et al., 1995, Bobrowsky et al., 1997a, 1997b; Bobrowsky et al., 1998). A 12 km^2 grid composed of 140 sample locations was surveyed and sampled northwest of the Faro deposits. Assay results for lead, zinc and copper were contoured and are presented in Figures 12 and 13 (see next page). The 1998 contoured geochemical maps are compared with equivalent geochemical results obtained from 1964 soil geochemistry. The presumed difference in the data sets is in the sampling and analytical procedures. The industry norm in 1964 was to collect B-horizon soils and assay the -80 mesh, whereas the technique employed in this study, as outlined earlier, focussed sampling below the soil horizons and assays on the -230 mesh fraction. The soil data obtained from the 1964 data set was interpolated to the 1998 sample locations from a more densely spaced soil grid in the same area.

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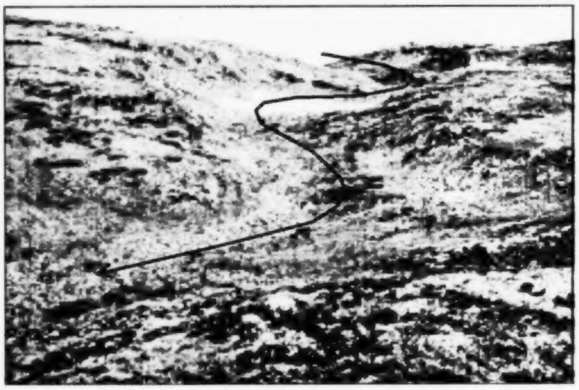

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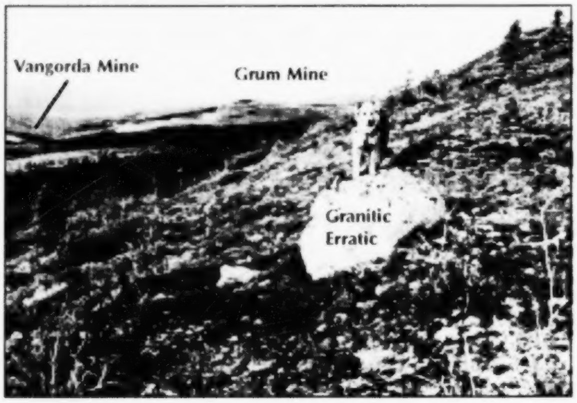

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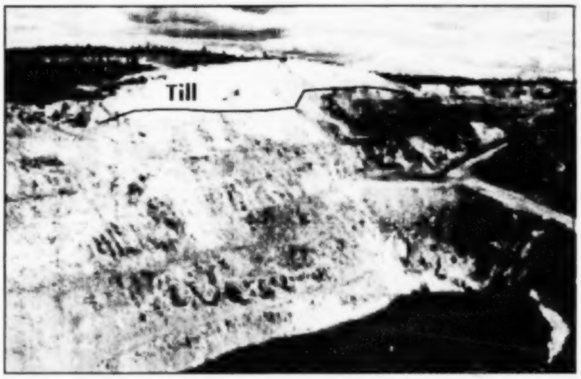

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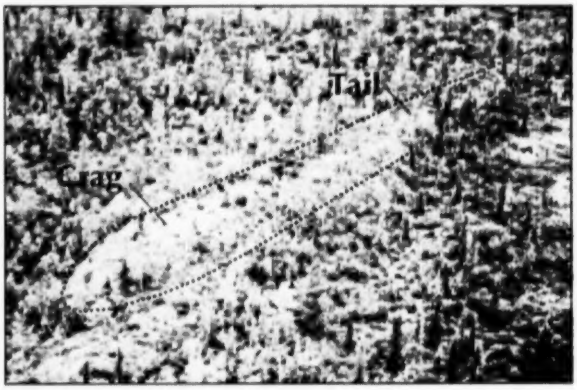

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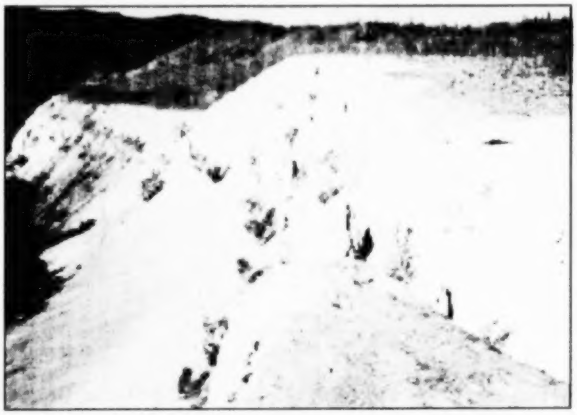

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RESULTS

Contoured results for lead, zinc, and copper are presented below for the 1998 and 1964 data.

The 1998 geochemical contours for lead data clearly show an increase towards the Faro deposit (Fig. 12a). The westward-oriented dispersion trend is consistent with ice-flow direction confined to Rose Creek valley and shows a slight drop in elevation with distance from the ore body. This reflects the progressive transport of subglacial debris into the valley bottom. In the vicinity of line 3 (L3), anomalous till values were mapped at higher elevations than the ore bodies.

Lead contours from the 1964 data show a narrow elongated plume to the west (Fig. 13a). Similarly, but more pronounced than the 1998 data, is a progressive reduction in elevation of the dispersion plume of 152 m (500 ft) over 4 km. In contrast to the 1998 data, the lead values from L3 at higher elevations are not anomalous.

The 1998 contoured geochemistry for zinc, like lead (1998), indicate a broad dispersion plume to the west extending beyond the sample grid (Fig. 12b). Contours show an extension of values that follow the topographic contours into Next Creek. Anomalies along the lower elevations of lines 3-7 are likely attributed to dispersal enrichment from the lower Faro deposit. An anomaly at the upper elevations of line 3 indicates proximal till enrichment 152 m (500 ft) above the source area.

The 1964 contoured geochemistry for zinc shows a well-defined dispersion plume almost 1.5 km wide by at least 4 km long with a narrow secondary anomalous ribbon near the top of the grid (Fig. 13b). The progressive

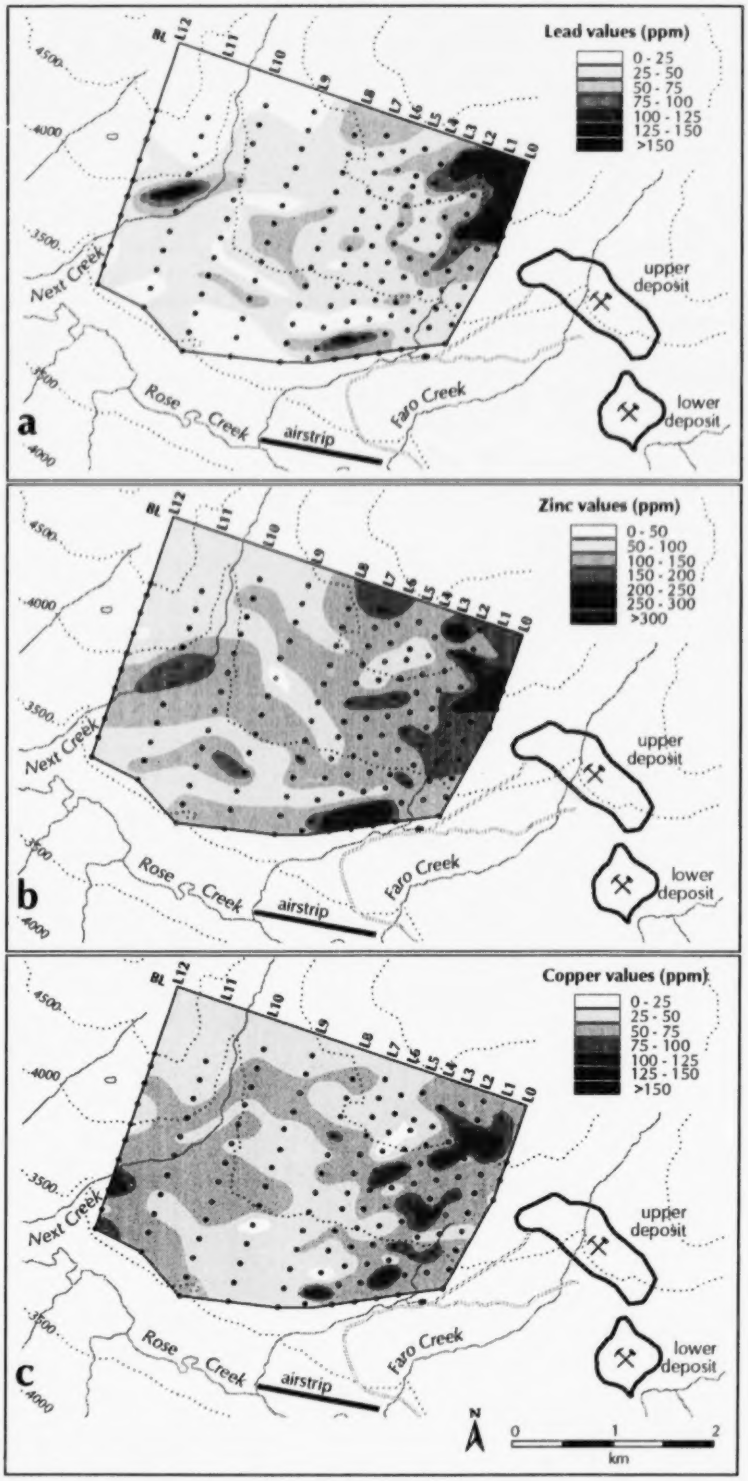
Lead values (ppm)
0 - 25
25 - 50
50 - 75
75 - 100
100 - 125
125 - 150
>150
Zinc values (ppm)
0 - 50
50 - 100
100 - 150
150 - 200
200 - 250
250 - 300
>300
Copper values (ppm)
0 - 25
25 - 50
50 - 75
75 - 100
100 - 125
125 - 150
>150
BL
L12
L11
L10
L9
L8
L7
L6
L5
L4
L3
L2
L1
L0
4500
4000
3500
0
Next Creek
Rose Creek
Faro Creek
airstrip
upper deposit
lower deposit
a
b
c
N
0
1
2
km

Figure 12. Contoured till geochemical values near the Faro ore deposits (1998 data). ***a)*** *Lead: note the higher concentrations above the elevation of the upper Faro deposit.* ***b)*** *Zinc: note the broad ameboid-shaped dispersion plume from the Faro deposits. The contours also conform to Next Creek valley.* ***c)*** *Copper: note the broad dispersion plume to the northwest with a strong gradient of values decreasing down-ice.*

down-slope trend of the plume is also well pronounced, with a distinct anomalous core to the main dispersal body.

The 1998 contoured geochemistry for copper shows a clear dispersal plume with the highest values occurring in the first 1.5 km west of the upper ore deposit (Fig. 12c). Ribbon shaped plumes continue down-valley beyond the grid and appear to conform into Next Creek valley. The highest copper values in till were obtained from the upper elevations of lines 1-3.

The 1964 contoured geochemistry for copper shows a 600 m wide ribbon shaped dispersion plume from the Faro deposits (Fig. 13c). A second ribbon-shaped plume is visible near the end of the grid in Next Creek valley.

DISCUSSION

DRIFT EXPLORATION CASE STUDY

The 1998 Faro till geochemistry case study outlined distinct dispersion plumes for each of lead, zinc, and copper. The primary dispersion plume can be traced directly to the upper Faro deposit, and in some instances to an anomalous area above the main ore bodies. For copper (1964 and 1998 data) and zinc (1964 data), a secondary dispersion plume is visible at the upper elevations of the grid between lines 8 and 12 that appears to be directed towards the anomalous area near the upper elevations of line 3. This can be explained as either a dispersion plume from anomalous bedrock or as a palimpsest dispersal train. Palimpsest dispersal trains are residual trains that are produced from multiple ice-flow

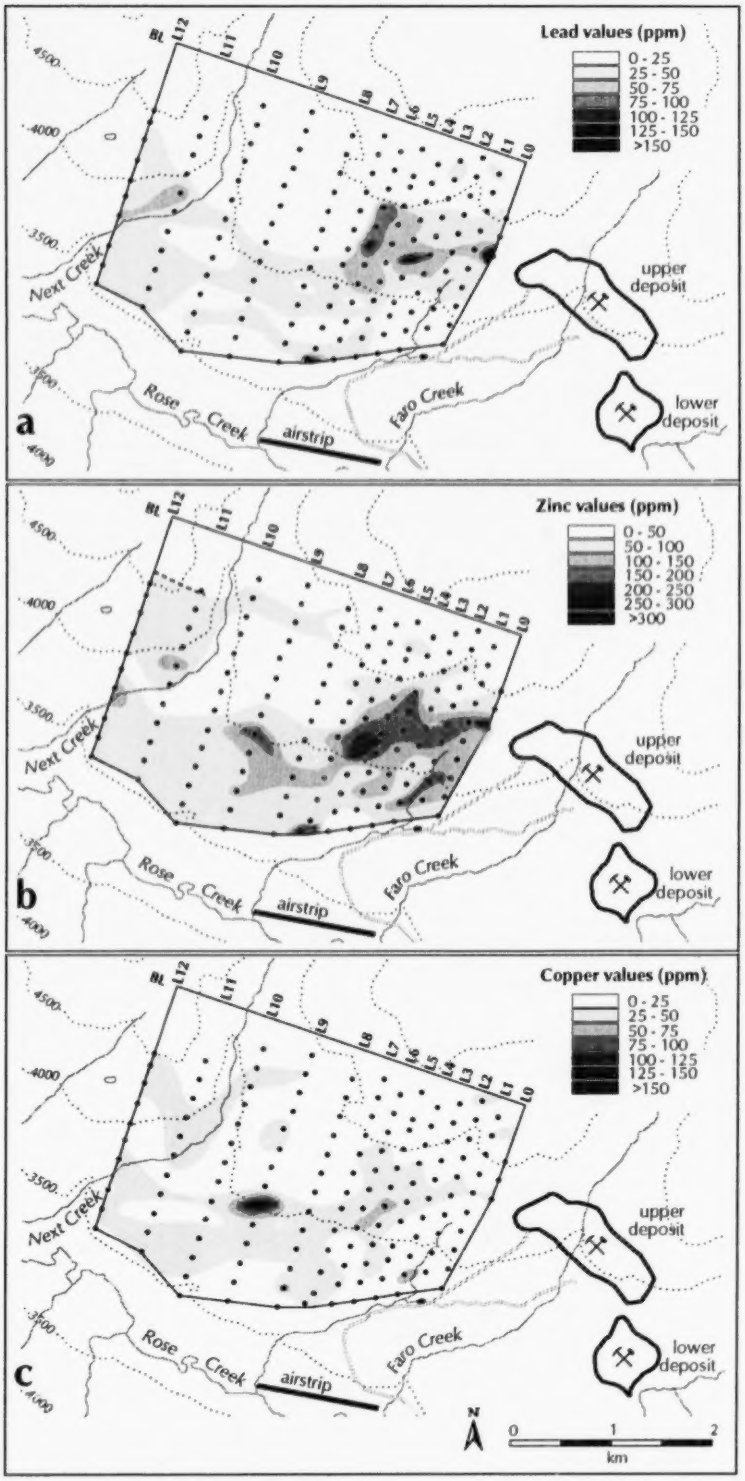
a
Lead values (ppm)
0 - 25
25 - 50
50 - 75
75 - 100
100 - 125
125 - 150
>150
b
Zinc values (ppm)
0 - 50
50 - 100
100 - 150
150 - 200
200 - 250
250 - 300
>300
c
Copper values (ppm)
0 - 25
25 - 50
50 - 75
75 - 100
100 - 125
125 - 150
>150
BL
L12
L11
L10
L9
L8
L7
L6
L5
L4
L3
L2
L1
L0
4500
4000
3500
0
Next Creek
Rose Creek
Faro Creek
airstrip
upper deposit
lower deposit
N
0
1
2
km

Figure 13. *Contoured geochemical soil values near the Faro ore deposits (1964 data).* ***a)*** *Lead: note the well-defined dispersion plume from the upper Faro deposit to the west.* ***b)*** *Zinc: note the well-defined dispersion plume from the upper Faro deposit and a second ribbon at a slightly higher elevation.* ***c)*** *Copper: the dispersion plume is well defined, however lacks a decreasing concentration gradient away from the Faro deposits.*

directions, in which an earlier dispersal train is incompletely re-entrained by later glacial movement (Parent et al., 1996). In short, it requires dispersion of a dispersion plume. A neighbouring, but topographically isolated till anomaly could thus indicate an early dispersion (ice-flow direction) related to a differing ice-flow direction. The isolated anomaly near the upper elevations of line 3 could have formed when converging glaciers in Rose Creek valley forced ice to flow subparallel to the contours. This northwest-trending plume was then re-dispersed or elongated by a change in flow direction to the west. Evidence for a bedrock source that might otherwise explain this dispersion plume is currently unknown in this area (Pigage, pers. comm.).

The 1998 geochemical contours show a broad dispersion plume from the source area, whereas the 1964 geochemical contours show a narrow and more direct dispersion plume. The utility of glacial dispersion and till geochemistry is apparent from either of the two data sets. Typically, soil sampling is used as a method to trace anomalies at the property scale. Results from this study suggest it has wider applications to regional- and intermediate-scale massive sulphide exploration in drift-covered terrain. By contrast, the 1964 contoured data emphasizes the utility of this technique as a method in local-scale exploration for massive sulphides sub-cropping in drift covered terrain. In the case of the Faro deposit, the dispersion plumes for lead and zinc in the 1964 data set point directly back to the source rocks.

To compare the two data sets, the Pb and Zn values from the 1998 and 1964 Faro grid lines are compared to a background value and a 95th percentile threshold derived from Swim Basin regional samples. The background threshold is equal to the median value and the 95th percentile is considered to be a higher end anomalous threshold. Swim Basin is considered to be the most representative area to calculate a regional threshold because of its similar geology, physiography and glacial history to the Vangorda Plateau. It should be noted that the threshold values calculated for these data sets are based solely on relative significance. From the 1998 Faro grid line data, 94% of the zinc and 100% of the lead values fell above the background levels of 76 and 14 ppm, respectively. When plotted relative to the regional 95th percentile, 6.5% of the zinc values and 66% of the lead values were above the upper thresholds of 203 and 32 ppm, respectively. From the 1964 data, 51% of the zinc values and 70% of the lead values fell above background levels of 62 and 13 ppm, respectively. When the 1964 Faro grid line values were plotted relative to the regional 95th percentile, 16% of the zinc values and 53% of the lead values were above the thresholds of 128 and 23 ppm, respectively.

From these results, a comparison of the significance of the geochemical dispersion trains mapped from the 1998 and 1964 data can be drawn. The percentage values indicate that the sample and analytical technique employed during the 1998 study returned significantly more values above background levels. For the 1998 data, 30% more lead values and 43% more zinc values are above background in comparison to the 1964 data. The comparison of values above the 95th percentile differed less between the two data sets. For lead, 13% more values in the 1998 data lie above the 95th percentile and for zinc, 10% more values in the 1964 data lie above the 95th percentile. In short, these results show that both methods recognized values above the 95th percentile. Significantly more lead values than zinc values for both data sets appear above the 95th percentile. This suggests that lead anomalies that fall above the 95th percentile, from soil or till samples, may be a more reliable indicator of a nearby sulphide deposit. When considering regional exploration for more subtle sulphide dispersions, the method used during the 1998 study was a more effective identifier of above-background values for both lead and zinc.

Glacial sedimentation into Next Creek basin could have important implications to its stream sediment geochemistry. The dispersion plumes from the 1998 data appear to conform to Next Creek valley which suggests the ice behaved much like a fluid rather than staying rigidly confined to Rose Creek valley. Glacial sedimentation of possible Faro float into Next Creek from a conforming glacier could register anomalous stream sediment values for lead, zinc, and copper in that basin. This provides a good example of how, when in glaciated terrain, glacial history must be considered in the interpretation of alluvial geochemistry.

LIMITATIONS

The limitations of till geochemical sampling centre on sample collection and processing. Determining a sample medium may often require exposing up to 1 m of the soil profile which can be a time-consuming process. Sediment identification is especially valuable, for instance, in valley systems where colluviation has amassed organic beds and resedimented till together in a near-surface deposit. Sampling a lens of resedimented till is certainly more applicable to a till sampling study than would be an organic-rich alluvium. This deposit structure may not be readily identified from a soil auger or B-horizon sample. In short, a comparison of drift geochemical data requires homogeneity in the sample medium to best qualify the data set. Secondly, the –230 mesh fraction in a Cordilleran basal till is not always an abundant sediment fraction which means taking a large sample to obtain a sufficient amount for procedures such as gold fire assays. It is also beneficial to collect 50-100 pebbles for boulder tracing and as a lithological reference if anomalous geochemical values are obtained. Sample preparation costs may also be inflated because sieving to –230 mesh requires additional time.

Permafrost may provide the greatest hindrance for the application of this technique in the north. Permafrost limits the depth to which a sample can be taken and causes a mixing of the soil through cryoturbation processes. At certain sample locations in the Anvil District, cryoturbation had essentially overturned the upper part of the soil column. For example, the White River ash, normally within 10 cm of the surface, was found in some areas at depths of 100 cm. Permafrost could also be variable within the soil column at a particular site. Unfrozen parent material was sometimes uncovered under a frozen pod of organic material. In the Anvil District, permafrost is most common where thick moss cover has accumulated on north-facing slopes and under mature forest cover.

SUMMARY

The Anvil District lies within the limits of the McConnell glaciation and is overlain by sediments originating from this glacial period. During the McConnell glaciation, ice from the Selwyn and Pelly mountains was funnelled into Tintina Trench and flowed north towards central Yukon. The location of the Anvil District adjacent to the Tintina Trench meant the Swim Basin and Vangorda Plateau were exposed to extreme glacial erosion and depositional processes. Till deposits on the Vangorda Plateau range in thickness from < 1 m to 200 m. During the late stages of glaciation, alpine ice retreated prior to the Cordilleran ice sheet which enabled Cordilleran ice to invade alpine valleys. Wholesale starvation of the ice sheet occurred shortly after, when the firn line dropped below 1830 m elevation for the Cordilleran ice sheet (Jackson, 1987).

Results of the 1998 till geochemistry case study, north of the Faro deposit, show a broad dispersion plume for lead, zinc, and copper, extending greater than 5 km west of the Faro deposits. Anomalous metal values in till proximal to the Faro deposit, but at a higher elevation, may indicate local anomalous bedrock or the presence of a palimpsest dispersal train.

The 1964 soil geochemistry data shows a well-defined, narrow dispersal train west of the Faro deposit. The core of the dispersion train can only be traced beyond the Faro deposit for 2.5 km for zinc and 1.5 km for lead.

Both methods recognized values above the 95th percentile, however significantly more lead values than zinc values appeared above the 95th percentile in both data sets. This suggests that lead anomalies that fall above the 95th percentile, from soil or till samples, may be more reliable indicators of nearby sulphide deposits than zinc. When considering regional exploration for more subtle sulphide dispersion the method used during this study was a more effective identifier of above-background values for both lead and zinc. This is consistent with findings by Shilts (1984) that show how weathering readily breaks down sulphide minerals and releases metals that are subsequently scavenged by the clay fraction. The geochemical signature of a weathered till is thus most strongly expressed in the clay fraction. The -80 mesh fraction seems best utilized in the mapping of dispersion trains at the property scale.

Finally, the dispersion plume also shows a movement of metals into a tributary valley oriented transverse to glacial ice flow. This suggests the ice behaved much like a fluid rather than a rigid mass confined to Rose Creek valley and exemplifies the process of stream sediment contamination by glacial dispersion.

ACKNOWLEDGEMENTS

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REFERENCES

Bobrowsky, P.T., Best, M., Dunn, C.E., Huntley, D.H., Lowe, C., Roberts, M., Seeman, D.A. and Sibbick, S.J.N., 1995. Integrated drift exploration studies on northern Vancouver Island (92L). *In:* Geological Fieldwork, 1994, B. Grant and J.M. Newell (eds.), B.C. Ministry of Energy, Mines, and Petroleum Resources, Paper 1995-1, p. 23-33.

Bobrowsky, P.T., Leboe, E.R., Dixon-Warren, A., Ledwon, A., MacDougall, D. and Sibbick, S.J., 1997b. Till geochemistry of the Adams Plateau-North Barriere Lake Area (82 M/4 and 5). British Columbia Ministry of Employment and Investment, Open File 1997-9. 1:50 000 scale map.

Bobrowsky, P.T., Paulen, R., Little, E., Prebble, A., Ledwon, A. and Lett, R., 1998. Till geochemistry of the Louis Creek-Chu Chua Creek area (NTS 92P/1E and 92P/8E). B.C. Ministry of Energy, Mines and Petroleum Resources, Open File 1998-6. 1:50 000 scale map.

Bond, J.D., 1997. Late Cenozoic history of McQuesten map area, Yukon Territory, with applications to placer gold research. Unpublished M.Sc. Thesis, University of Alberta, Edmonton, Alberta, 161 p.

Bostock, H.S., 1966. Notes on glaciation in central Yukon Territory; Geological Survey of Canada, Paper 65-36, 18 p.

Gabrielse, H., 1967. Tectonic evolution of the northern Canadian Cordillera. Canadian Journal of Earth Sciences, vol. 4, p. 271-298.

Giles, T.R. and Kerr, D.E., 1993. Surficial geology in the Chilanko Forks and Chezacut areas (93C/1, 8). *In:* Geologic Fieldwork 1992, B. Grant and J.M. Newell (eds.), British Columbia Ministry of Energy, Mines and Petroleum Resources, Paper 1993-1, p. 483-490.

Jackson, L.E., 1987. Terrain inventory and Quaternary history of Nahanni map area, Yukon Territory and Northwest Territories. Geological Survey of Canada, Paper 86-18, 20 p.

Jackson, L.E., 1991. Pleistocene mammals, stratigraphy, and sedimentology at the Ketza River site, Yukon Territory. Geographie Physique et Quaternaire, vol. 49, p. 69-77.

Jackson, L.E., 1994. Terrain inventory and Quaternary history of the Pelly River area, Yukon Territory. Geological Survey of Canada, Memoir 437, 41 p.

Jennings, D.S. and Jilson, G.A., 1986. Geology and sulphide deposits of Anvil Range, Yukon. *In:* Mineral deposits of Northern Cordillera, J.A. Morin (ed.), Canadian Institute of Mining and Metallurgy, Special Vol. 37, p. 319-361.

Levson, V.M. and Giles, T.R., 1994a. Surficial geology and Quaternary stratigraphy of the Fawnie Creek area (NTS 93 F/3). British Columbia Ministry of Energy, Mines and Petroleum Resources, Open File 1994-9, 1:50 000 scale map.

Levson, V.M. and Giles, T.R., 1994b. Glacial dispersion patterns of mineralized bedrock with examples from the Nechako Plateau, central British Columbia. B.C. Ministry of Energy, Mines and Petroleum Resources, Drift Exploration in Glaciated and Mountainous Terrain, Short Course Notes, Cordilleran Roundup, Vancouver, B.C., 13 p.

Levson, V.M., Giles, T.R., Cook, S.J. and Jackaman, W., 1994c. Till geochemistry of the Fawnie Creek map area (NTS 93 F/3). British Columbia Ministry of Energy, Mines and Petroleum Resources, Open File 1994-18.

Nikkarinen, M., Kallio, E., Lestinen, P. and Ayras, M., 1983. Mode of occurrence of copper and zinc in till over mineralized bedrock (abstr.). *In:* X IGES-III SMGP, Finland 1983, Abstracts, A. Bjorklund and T. Kolijonen (eds.), Geological Survey of Finland, Espoo Finland, p. 54-55.

Parent, M., Paradis, S.J. and Doiron, A., 1996. Palimpsest glacial dispersal trains and their significance for drift prospecting. Journal of Geochemical Exploration, vol. 56, p.123-140.

Pigage, L.C., 1990. Field guide to the Anvil Pb-Zn-Ag District, Yukon Territory, Canada. *In:* Mineral Deposits of the Northern Canadian Cordillera, Yukon-Northeastern B.C, 8th IAGOD Symposium Field Trip Guide Book, J.G. Abbott and R.J.W. Turner (eds.), Geological Survey of Canada, Open File 2129; p. 283-308.

Pigage, L., 1999 (this volume). Preliminary geology of Rose Mountain, Anvil District, central Yukon (105K/05). *In:* Yukon Exploration and Geology 1998, C.F. Roots and D.S. Emond (eds.), Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 91-103.

Shilts, W.W., 1976. Glacial till and mineral exploration. *In:* Glacial Till, R.F. Legget (ed.), Royal Society of Canada, Special Publication 12, p. 205-223.

Shilts, W.W., 1984. Till geochemistry in Finland and Canada. Journal of Geochemical Exploration, vol. 21, p. 95-117

Ward, B.C., 1989. Quaternary stratigraphy along Pelly River in Glenlyon and Carmacks map areas, Yukon Territory. *In:* Current Research, Part E, Geological Survey of Canada, Paper 89-1E, p. 257-264.

The geology of placer gold deposits in the Indian River area, west-central Yukon

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Lowey, G.W., 1999. The geology of placer gold deposits in the Indian River area, west-central Yukon. *In:* Yukon Exploration and Geology 1998, C.F. Roots and D.S. Emond (eds.), Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 117-124.

ABSTRACT

Placer gold deposits in the Indian River area, west-central Yukon, are grouped into five classes based on thickness, grain size, composition, age, process, landform and exposure. The placers vary from 1.5-16 m in thickness and consist of slightly muddy, sandy gravel that is dominated by either vein quartz clasts, or igneous and metamorphic clasts. The gravel was deposited on floodplains, now preserved as terraces and creek and river valley fills, that range from Pliocene(?) to Holocene in age. The formation of the placers is related to a hierarchy of physical scales: at the *lithofacies* scale (m's), bed roughness determined sites of gold deposition; at the *element* scale (10's of m's), gravel bars were preferentially enriched in gold; at the *reach* scale (100's of m's), stream gradient was an important factor; at the *system* scale (100's of km's), braided river environments transported large amounts of gold; and at the *sequence* scale (1,000's of km^2), economic placers formed in the White Channel Gravel unit in downstream parts of the Indian River drainage, and in upstream parts of the drainage in the unit herein referred to as the Local Creek Gravel.

RÉSUMÉ

Les gîtes d'or placériens de la région de la rivière Indian, dans la partie centrale ouest du Yukon, sont regroupés en cinq classes en fonction de l'épaisseur, de la granulométrie, de la composition, de l'âge, des formes de terrain et de l'exposition. L'épaisseur des gîtes placériens varie de 1,5 à 16 m et ils consistent en gravier sablonneux légèrement boueux dans lequel prédominent des clastes de quartz filonien ou des clastes ignés ou métamorphiques. Le gravier s'est déposé dans des plaines inondables aujourd'hui conservées sous forme de terrasses et de vallées de ruisseaux et de rivières dont l'âge varie du Pliocène(?) à l'Holocène. La formation des placers est reliée à une hiérarchie d'échelles physiques: à l'échelle du *lithofaciès* (de l'ordre du mètre), la rugosité du fond détermine les emplacements de dépôt de l'or; à l'échelle de *l'élément* (dizaine de mètres), des barres de gravier ont été enrichies en or de manière préférentielle; à l'échelle du *tronçon* (centaine de mètres), la pente du cours d'eau était un facteur important; à l'échelle du *réseau* (centaine de kilomètres), les cours d'eau anastomosés transportaient de grandes quantités d'or et à l'échelle de la *séquence* (milliers de kilomètres carrés), des placers rentables se sont formés dans les graviers de l'unité de White Channel dans les parties aval du bassin de la rivière Indian et dans les parties amont du bassin dans les graviers de l'unité ici désignée de Local Creek.

INTRODUCTION

The Indian River area, located south of Dawson City in west-central Yukon (Fig. 1), forms the northeast corner of the Stewart River map sheet (115 O&N). The main gold bearing streams are the Indian River, Quartz Creek, Montana Creek, Eureka Creek, Sulphur Creek, Dominion Creek, Gold Run Creek and Caribou Creek (Fig. 2). The Indian River drainage is the southernmost limit of the world-famous Klondike gold fields.

The first payable gold from the Klondike was mined in 1894 at Quartz Creek by William "Billy" Redford (Coutts, 1980). Despite continuous mining for over 100 years, the Indian River drainage has recently been the most important placer area in the Yukon, accounting for nearly 44% of the placer gold production during 1995-97 (Mining Inspection Division, 1998).

One of the most important conclusions following the Placer Mine Panel Discussion which was held in Whitehorse in November, 1997 as part of the Yukon Geoscience Forum, is that we know a lot about placers at the local, or outcrop scale and at the regional, or glacial limits scale, but we know very little about placers at the intermediate, or drainage basin scale. This study represents the first systematic and detailed investigation of placers in the Indian River drainage. Its purpose is to describe the placers, interpret their formation, and apply this information to placer exploration and mining.

BEDROCK GEOLOGY

Although dated, Bostock's (1942) map provides the most complete coverage of the bedrock geology in the Indian River area. More recent mapping was done by Debicki (1985) and Mortensen (1990, 1996) north of the Indian River, and by Lowey (1982, 1983, 1985) and Lowey and Hills (1988) south of the river. Knight et al. (1994) investigated major and minor trace element compositions of lode and placer gold from the Klondike, and concluded that the placer gold is detrital in origin and was derived from quartz veins present in the bedrock. Rushton et al. (1993) showed that the quartz veins are part of a mesothermal vein system.

The Indian River area is underlain by mainly Paleozoic metasedimentary (i.e., Kondike Schist and Nasina Assemblage) and meta-igneous rocks belonging to the Yukon-Tanana Terrane (Mortensen, 1996). Minor amounts of altered ultramafic rocks occur locally and are assigned to the Slide Mountain Terrane. According to Mortensen (1996), these two pre-accretionary units were juxtaposed by regional-scale thrust faulting in Early Mesozoic time. The gold-bearing quartz veins were emplaced in the earliest Cretaceous (Rushton et al., 1993), and the area was then unconformably overlain by post-accretionary sedimentary and volcanic rocks in mid- to late Cretaceous time. Lowey and Hills (1988) assigned the sedimentary rocks, in part, to the Tantalus Formation, and Lowey et al. (1986) assigned the volcanic rocks, in part, to the Carmacks Group.

SURFICIAL GEOLOGY

Bostock (1966) and Hughes et al. (1969) provide a regional framework for the surficial geology and glacial history of the Indian River area. Only very restricted surficial mapping (e.g., Morison et al., 1998) has been carried out in the area, although further mapping is planned as part of a proposed NATMAP project (L. Jackson, pers. com., 1998). Limited information on the type of surficial geology units present in the area can be obtained from the Dawson map sheet (located immediately to the north of the Stewart River map sheet) which was mapped by Vernon and Hughes (1966) and more recently by Duk-Rodkin (1996).

The Indian River area, thought to be a mature, subdued landscape by Miocene time, underwent a period of uplift and erosion in the Pliocene (Tempelman-Kluit, 1980). The area was not covered by glacial ice during the pre-Reid (latest Pliocene in age) or later glaciations. However, glacial outwash (i.e., the Klondike Gravel) was deposited on high-level terraces along the Indian River

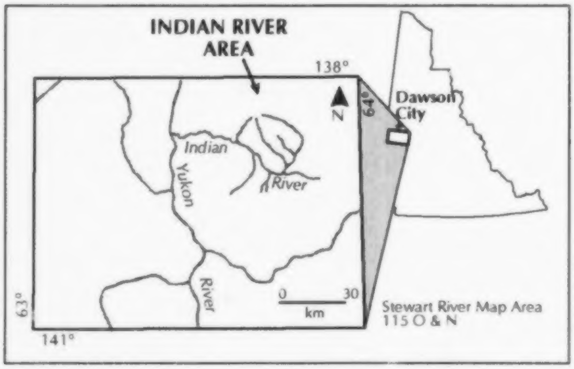


Figure 1. Location map of the Indian River area, west-central Yukon.

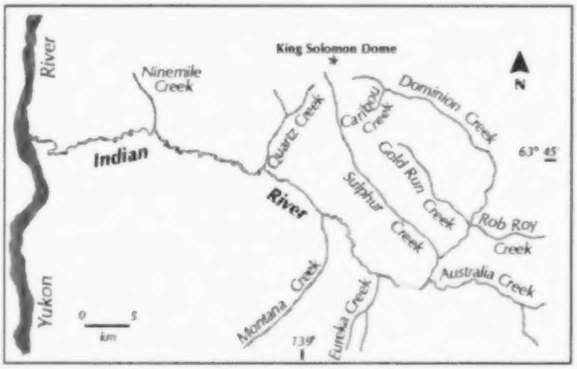


Figure 2. Main placer gold-bearing streams in the Indian River area.

(Hughes et al., 1969). Duk-Rodkin (1996) has mapped some of the placer deposits as slope complexes (map unit Cx).

METHODS

This study is based on field work and preliminary laboratory analyses. Field work involved visits to 20 active placer mines and 10 inactive placer mines from June to September, 1997. During these visits, outcrop profiles of the deposits were constructed according to the method outlined by Miall (1996), and representative samples were collected. Ongoing laboratory work includes determining the grain size distribution and clast lithology of gravel samples, palynological analysis of fine-grained sand and silt samples, and radiometric age dating of tephra and organic samples. Outcrop profiles are tentatively correlated by lithocorrelation (cf. Schoch, 1989) which will be confirmed by chronocorrelation once radiometric age dates are available.

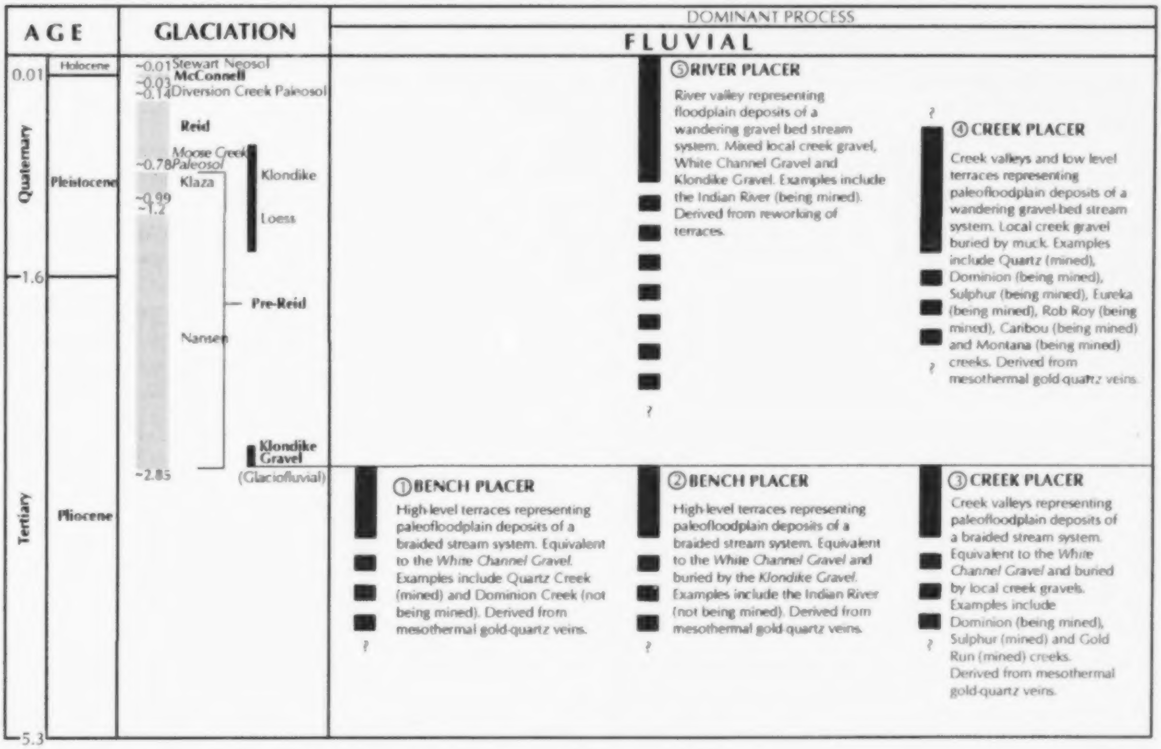
PLACER GEOLOGY

McConnell's (1905) paper on the Klondike gold fields includes the most comprehensive description available of placers in the Indian River drainage, and he was the first to correctly interpret the origin of the placer gold. The report by Gleeson (1970) provides a description of the type and distribution of heavy minerals present in the placers, as well as regional trends in gold fineness. A synopsis (including descriptions of gravel mined and gold recovered) of placer mines in the area can be found in the Mining Inspection Division (1998) report, as well as in earlier placer industry reports (Indian and Northern Affairs Canada).

DESCRIPTION OF PLACER DEPOSITS

The placer deposits can be grouped into five classes (Fig. 3) on the basis of thickness, grain size, composition, age, dominant sedimentary process (e.g., fluvial, mass wasting, weathering, etc.), type of landform (e.g., terrace, valley, etc.), and exposure (e.g., exposed on the surface, buried, or exhumed).

Placer Deposit 1 occurs along Quartz Creek, where it forms high-level terraces (Fig. 4). The terraces consist of approximately 16 m of slightly muddy, sandy gravel that is dominated by vein quartz clasts (Fig. 5). The gravel is interpreted to be Pliocene(?) in age, and represents paleofloodplain deposits of a braided stream. It is assigned to the White Channel Gravel unit which forms the prominent terraces on Bonanza and Hunker creeks (McConnell, 1905, 1907; Lowey, 1998).



River valley representing floodplain deposits of a wandering gravel bed stream system. Mixed local creek gravel, White Channel Gravel and Klondike Gravel. Examples include the Indian River (being mined). Derived from reworking of terraces.

Creek valleys and low level terraces representing paleofloodplain deposits of a wandering gravel-bed stream system. Local creek gravel buried by muck. Examples include Quartz (mined), Dominion (being mined), Sulphur (being mined), Eureka (being mined), Rob Roy (being mined), Caribou (being mined) and Montana (being mined) creeks. Derived from mesothermal gold-quartz veins.

High-level terraces representing paleofloodplain deposits of a braided stream system. Equivalent to the *White Channel Gravel*. Examples include Quartz Creek (mined) and Dominion Creek (not being mined). Derived from mesothermal gold-quartz veins.

High-level terraces representing paleofloodplain deposits of a braided stream system. Equivalent to the *White Channel Gravel* and buried by the *Klondike Gravel*. Examples include the Indian River (not being mined). Derived from mesothermal gold-quartz veins.

Creek valleys representing paleofloodplain deposits of a braided stream system. Equivalent to the *White Channel Gravel* and buried by local creek gravels. Examples include Dominion (being mined), Sulphur (mined) and Gold Run (mined) creeks. Derived from mesothermal gold-quartz veins.

Figure 3. *Classification of placer deposits in the Indian River area.*

Placer Deposit 2 occurs along the Indian River, where it forms high-level terraces (Fig. 6). The terraces consist of approximately 16 m of slightly muddy, sandy gravel that is dominated by vein quartz clasts (Fig. 7). The gravel is also interpreted as Pliocene(?), and represents paleofloodplain deposits of a braided stream. It too is assigned to the White Channel Gravel unit. The White Channel Gravel of this deposit type is buried by the Klondike Gravel which is composed of vein quartz, igneous, metamorphic, and sedimentary clasts, and represents glacial outwash (Hughes et al.,1969).

Placer Deposit 3 occurs along the lower part of Dominion, Sulphur and Gold Run creeks, where it forms the fill of the creek valleys (Fig. 8). The creek valley fill consists of approximately 5 m of slightly muddy, sandy gravel that is dominated by vein quartz clasts (Fig. 9). The gravel is interpreted to be Pliocene(?) in age, and represents paleofloodplain deposits of a creek. It is also assigned to the White Channel Gravel unit. The White Channel Gravel of this deposit type is buried by local creek gravel which is dominated by igneous and metamorphic clasts.

Placer Deposit 4 occurs along Montana, Eureka and Caribou creeks, and along the upper part of Sulphur, Gold Run and Dominion creeks, where it forms the fill of the creek valleys (Fig. 10). The creek valley fill consists of approximately 2 m of slightly muddy, sandy gravel that is dominated by igneous and metamorphic clasts (Fig. 11). The gravel is interpreted to be Pliestocene(?) in age, and represents paleofloodplain deposits of a creek. It is assigned to the Local Creek Gravel unit.

Placer Deposit 5 occurs along the Indian River, where it forms the fill of the present day river (Fig. 12). The river fill consists of approximately 1.5 m of slightly muddy, sandy gravel that is

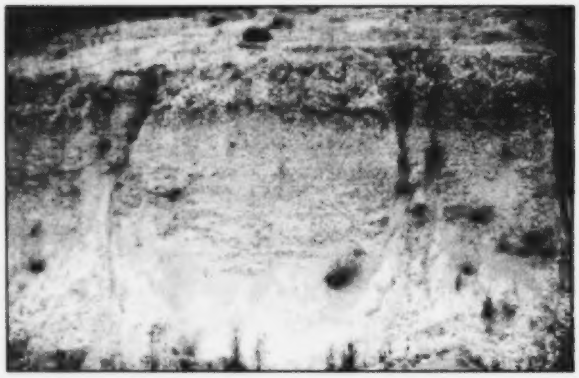


Figure 4. *Photograph of gravel exposed on terraces along Quartz Creek.*

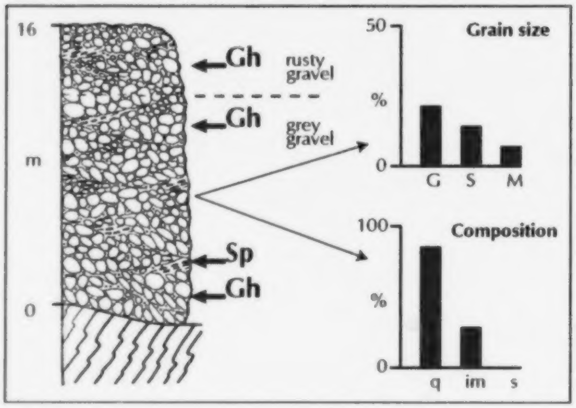


Figure 5. *General stratigraphic section of Placer Deposit 1 and typical grain size distribution and composition of gravel.*

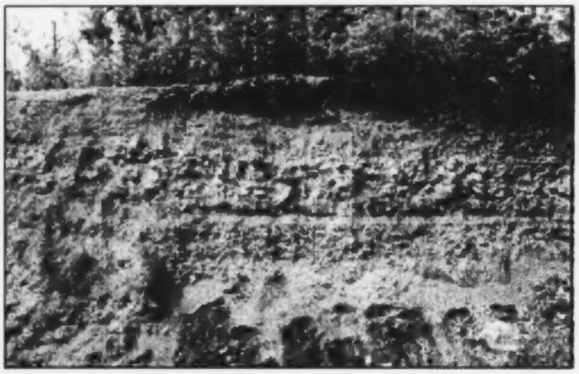


Figure 6. *Photograph of gravel exposed on terraces along the Indian River.*

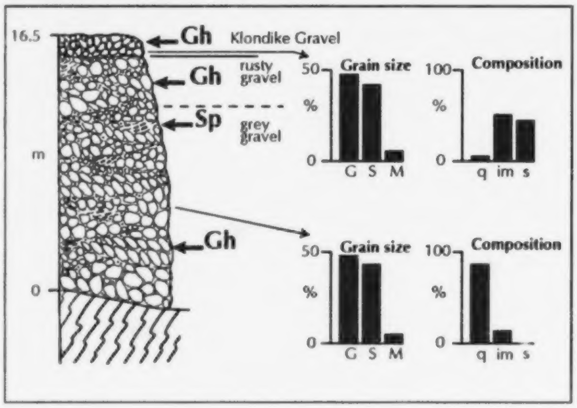


Figure 7. *General stratigraphic section of Placer Deposit 2 and typical grain size distribution and composition of gravel.*

Gh=horizontally bedded gravel
Sp=planar bedded sand
G=gravel
S=sand
M=mud
q=quartz vein clast
im=igneous and metamorphic clasts
s=sedimentary clasts

characterized by a mixed lithology of vein quartz, igneous, metamorphic, and sedimentary clasts (Fig. 13). Most of the vein quartz clasts were derived from the White Channel Gravel, whereas the sedimentary clasts were derived from reworking of the Klondike Gravel. Both units are exposed in high-level terraces along the river. The gravel is interpreted to be Holocene in age, and represents paleofloodplain deposits of a wandering gravel-bed river. It is assigned to the Mixed Gravel unit.

FORMATION OF PLACER DEPOSITS

All of the placer deposits are fluvial in origin, and a very important concept in fluvial sedimentology is that different depositional processes operate at different physical scales (Miall, 1996). A five-fold hierarchy of physical scales — from the outcrop (the smallest size) to the entire drainage area (the largest size) — can be recognized in placer deposits of the Indian River drainage (Fig. 14).

The lithofacies scale is metres in size (and days in duration) and represents beds classified on the basis of grain size, texture, and sedimentary structures. Typical lithofacies present are Gh (i.e., gravel that is horizontally bedded), Gp (i.e., gravel that is planar bedded) and Sp (i.e., sand that is planar bedded). At this scale, the important processes forming placers are entrainment sorting, dispersive sorting, suspension sorting (Slingerland, 1984) and bed roughness (Day and Fletcher, 1991). The bed roughness, or unevenness of the gravel pavement, is probably

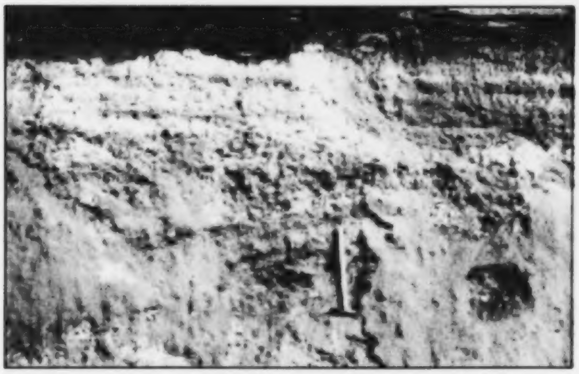


Figure 8. Photograph of gravel exposed in a placer mine pit on Dominion Creek.

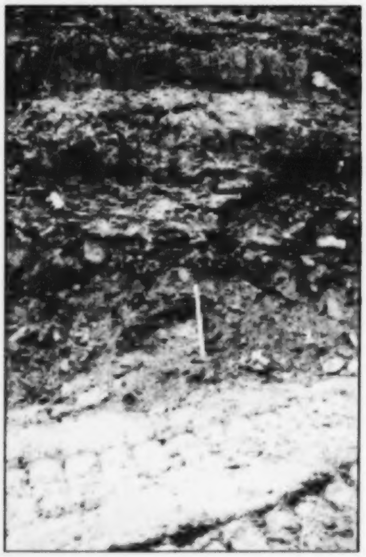


Figure 10. Photograph of gravel exposed in a placer mine pit on Caribou Creek.

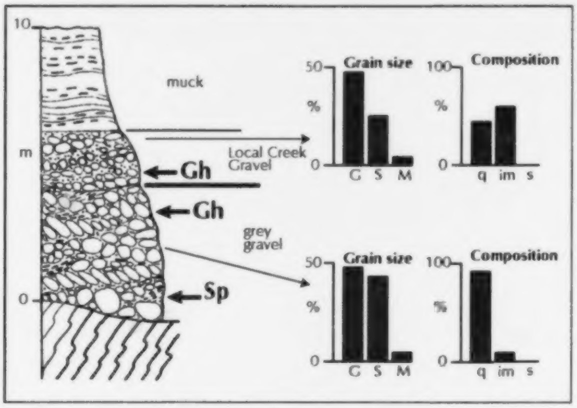


Figure 9. General stratigraphic section of Placer Deposit 3 and typical grain size distribution and composition of gravel.

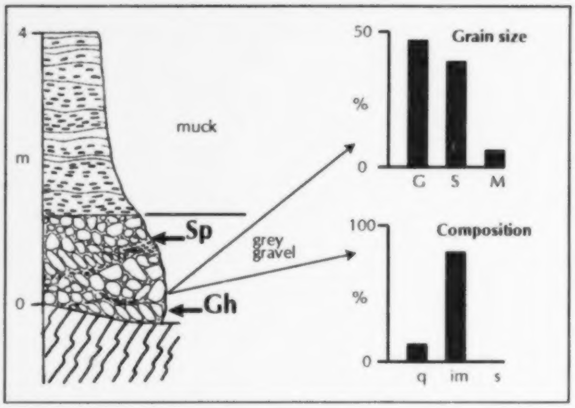


Figure 11. General stratigraphic section of Placer Deposit 4 and typical grain size distribution and composition of gravel.

Gh=*horizontally bedded gravel*
Sp=*planar bedded sand*
G=*gravel*
S=*sand*
M=*mud*
q=*quartz vein clast*
im=*igneous and metamorphic clasts*
s=*sedimentary clasts*

the most important process because this acts like a sluice to trap the gold. Hence, gravel lithofacies, particularly Gh, are preferentially enriched in gold relative to sand lithofacies.

The element scale is 10's of metres in size (and years in duration) and represents an assemblage of lithofacies. Typical elements are GB (i.e., gravel bars), SB (i.e., sand bars), and CH (i.e., channel fill deposits). At this scale the important process forming placers is the accumulation of gravel beds (i.e., lithofacies Gh) into gravel bars (i.e., element GB). Hence, gravel bars become enriched in gold relative to sand bars because the gravel bars are made up of the gold-bearing gravel beds.

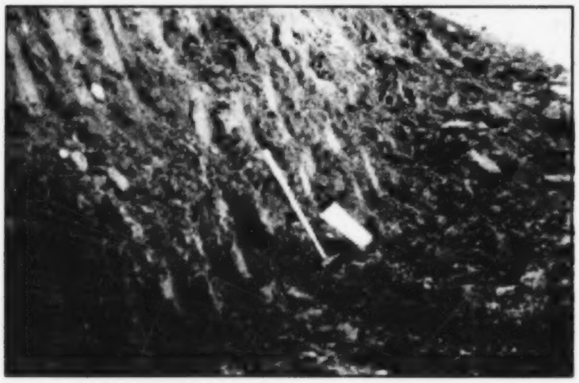


Figure 12. *Photograph of gravel exposed in a placer mine pit on the Indian River.*

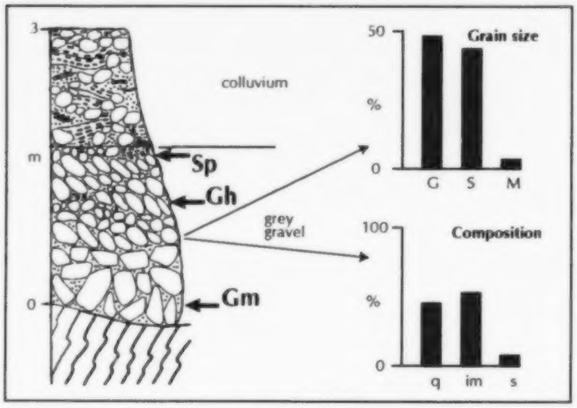

3
m
0
colluvium
Sp
Gh
grey gravel
Gm
50
Grain size
%
0
G
S
M
100
Composition
%
0
q
im
s

Figure 13. *General stratigraphic section of Placer Deposit 5 and typical grain size distribution and composition of gravel.*

Gh*=horizontally bedded gravel*
Sp*=planar bedded sand*
G*=gravel*
S*=sand*
M*=mud*
q*=quartz vein clast*
im*=igneous and metamorphic clasts*
s*=sedimentary clasts*

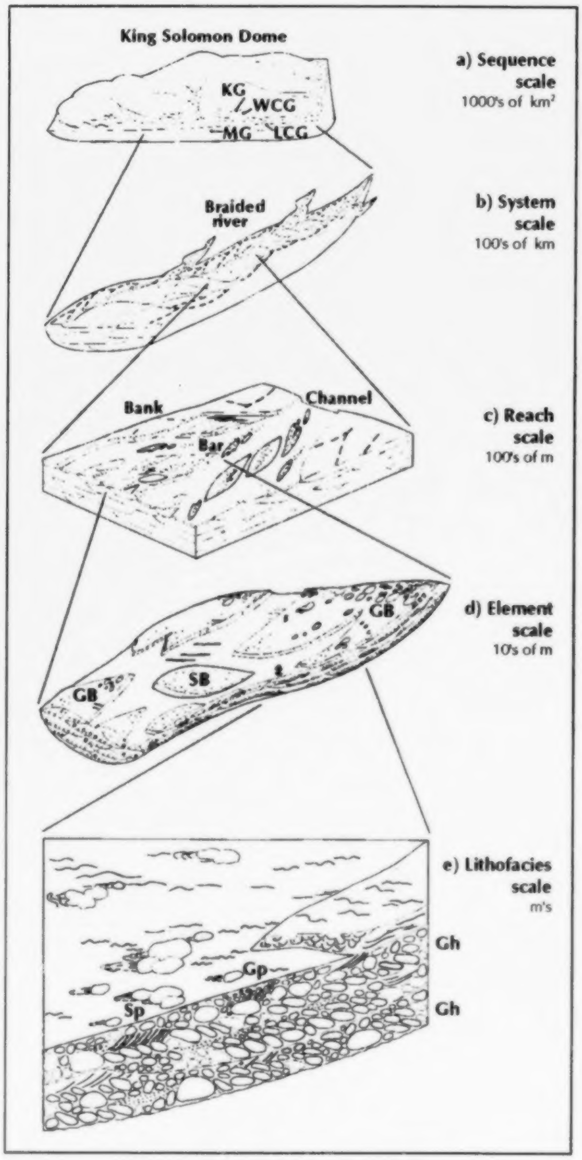

King Solomon Dome
KG
WCG
MG
LCG
a) Sequence scale
1000's of km²
Braided river
b) System scale
100's of km
Bank
Channel
Bar
c) Reach scale
100's of m
GB
SB
GB
d) Element scale
10's of m
Gh
Gp
Sp
Gh
e) Lithofacies scale
m's

Figure 14. *Fivefold hierarchy of physical scales related to formation of placer deposits:* ***a)*** *sequence scale (the Indian River drainage looking north towards King Solomon Dome);* ***b)*** *system scale;* ***c)*** *reach scale;* ***d)*** *element scale;* ***e)*** *lithofacies scale.*

KG*=Klondike gravel*
WCG*=White Channel gravel*
LCG*=local creek gravel*
MG*=mixed gravel*
GB*=gravel bar*
SB*=sand bar*
Gh*=horizontally bedded gravel*
Gp*=planar bedded gravel*
Sp*=planar bedded sand*

The reach scale is 100's of metres in size (and 10's of years in duration) and represents a continuous length of a stream channel (including the bars, smaller channels and banks). At this scale, the important processes forming placers are stream junctions (Mosley and Schumm, 1977) and the gradient of the stream (Hester, 1970). The stream gradient, or slope of the stream channel, is probably the most important factor because this controls the velocity of the stream flow, and the velocity of the stream flow determines the transportation, and deposition of the alluvium and the gold. Generally, the lower the stream gradient, the greater the potential for deposition of gold (Hester, 1970).

The system scale is 100's of kilometres in size (and 100's of years in duration) and represents a sedimentary environment, such as a river or alluvial fan. The braided river environment (characterized by many channels separated by small bars or islands, and coarse-grained alluvium) deposited most of the placers in the Indian River drainage.

The sequence scale is 1000's of square kilometres in size (and 1000's of years in duration) and represents mappable stratigraphic units (i.e., formations or members) made up of one or more sedimentary environments. Of the four gravel units recognized in the Indian River drainage, the White Channel Gravel, Local Creek Gravel, and Mixed Gravel formed economical placers. Note that Placer Deposits 1, 2 and 3 all belong to the same stratigraphic unit (i.e., the White Channel Gravel), but the deposits differ according to landform (e.g., terrace or creek valley) and expression (e.g., exposed on the surface or buried by the Klondike Gravel or Local Creek Gravel).

APPLICATION TO EXPLORATION AND MINING

The hierarchy concept of physical scales has important implications regarding placer exploration and mining. For example, the lithofacies scale should be considered during exploration, particularly when panning grab samples and drill cuttings because coarse-grained sediments (i.e., lithofacies Gh) trap more gold. Generally, this scale is too small to take into account when mining (i.e., an entire lithofacies or bed would be mined).

The element scale should be considered during exploration, particularly when evaluating drill results because gravel bars (element GB), especially the upstream ends of the bars, are preferentially enriched in gold relative to sand bars (element SB). Generally, this scale also is too small to take into account when mining.

The reach scale should be considered during exploration and when mining because lower steam gradients have greater potential for placer gold deposition. Detailed drill spacing may reveal the original gradient of the stream channel, and this information can be used to identify blocks of ground that contain potentially higher concentrations of gold.

The system scale should be taken into account during exploration because only coarse-grained fluvial deposits carry economic concentrations of gold. Generally, this scale is too large to take into account when mining (i.e., only a part of a system or sedimentary environment would be mined).

The sequence scale should be considered during exploration because only certain stratigraphic units are gold-bearing, such as the White Channel Gravel (which tends to form in the lower part of the Indian River drainage), and the Local Creek Gravel (which tends to form in the upper part of the drainage). Generally, this scale is also too large to take into account when mining.

ACKNOWLEDGEMENTS

This study would not have been possible without the cooperation of the placer miners in the area, and I would like to thank them for allowing access to their properties.

REFERENCES

Bostock, H.S., 1942. Ogilvie, Yukon Territory. Geological Survey of Canada, Map 71A (1:253 440 scale map with marginal notes).

Bostock, H.S., 1966. Notes on glaciation in central Yukon Territory. Geological Survey of Canada, Paper 65-36, 19 p.

Coutts, R.C., 1980. Yukon places and names. Gray's Publishing Limited, Sidney, British Columbia, 294 p.

Day, S.J. and Fletcher, W.K., 1991. Concentration of magnetite and gold at bar and reach scales in a gravel-bed stream, British Columbia, Canada. Journal of Sedimentary Petrology, vol. 61, p. 871-882.

Debicki, R.L., 1985. Bedrock geology and mineralization of the Klondike area (east), 115 0/9, 10, 11, 14, 15, 16 and 116 B/2. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, Open File 1985-1 (1:50 000 scale map and marginal notes).

Duk-Rodkin, A., 1996. Surficial geology, Dawson, Yukon Territory. Geological Survey of Canada, Open File 3288 (1:250 000 scale map with marginal notes).

Gleeson, C.F., 1970. Heavy mineral studies in the Klondike area, Yukon Territory. Geological Survey of Canada, Bulletin 173, 63 p.

Hester, B.W., 1970. Geology and evaluation of placer gold deposits in the Klondike area, Yukon Territory. Canadian Institute of Mining and Metallurgy, Transactions vol. 9, p. B60-B67.

Hughes, O.L, Campbell, R.B., Muller, J.E. and Wheeler, J.O., 1969. Glacial limits and flow patterns, Yukon Territory, south of 65 degrees north latitude. Geological Survey of Canada, Paper 68-34, 9 p.

Knight, J.B., Mortensen, J.K. and Morison, S.R., 1994. Shape and composition of lode and placer gold from the Klondike district, Yukon, Canada. Exploration and Geological Services, Yukon, Indian and Northern Affairs Canada, Bulletin 3, 142 p.

Lowey, G.W., 1982. Preliminary report on Early Tertiary clastics, west-central Yukon. *In:* Yukon Exploration and Geology 1981, Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 51-57.

Lowey, G.W., 1983. Report of 1982 field work on Early Tertiary clastics, west-central Yukon. *In:* Yukon Exploration and Geology 1982, Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 34-37.

Lowey, G.W., 1985. Auriferous conglomerates at McKinnon Creek, west-central Yukon (115 O 11): paleoplacer or epithermal mineralization? *In:* Yukon Exploration and Geology 1983, Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada p. 69-77.

Lowey, G.W., 1998. White Channel gravel. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, Open File 1998-2 (1:100 000 scale map and marginal notes).

Lowey, G.W. and Hills, L.V., 1988. Lithofacies, petrography and environments of deposition, Tantalus Formation (Lower Cretaceous) Indian River area, west-central Yukon. Bulletin of Canadian Petroleum Geology, vol. 36, p. 296-310.

Lowey, G.W., Sinclair, W.D. and Hills, L.V., 1986. Additional K-Ar dates for the Carmacks Group (Upper Cretaceous), west-central Yukon. Canadian Journal of Earth Sciences, vol. 23, p. 1857-1859.

McConnell, R.G., 1905. Report on the Klondike gold fields. Geological Survey of Canada, Annual Report, pt. B, vol. 14, p. 1-71.

McConnell, R.G., 1907. Report on gold values in the Klondike high level gravels. Geological Survey of Canada, Report no. 979, 34 p.

Miall, A.D., 1996. The geology of fluvial deposits: sedimentary facies, basin analysis, and petroleum geology. New York, Springer-Verlag, 582 p.

Mining Inspection Division, 1998. Yukon Placer Industry 1995-1997. Mineral Resources Directorate, Yukon, Indian and Northern Affairs Canada, 173 p.

Morison, S.R., Mougeot, C. and Walton, L., 1998. Surficial geology and sedimentology of Garner Creek, Ogilvie and Matson Creek map areas, western Yukon Territory (115O/13, 115O/12, 115N/9-east half). Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, Open File 1998-1, 88 p.

Mortensen, J.K., 1990. Geology and U-Pb chronology of the Klondike District, west-central Yukon Territory. Canadian Journal of Earth Sciences, vol. 27, p. 903-914.

Mortensen, J.K., 1996. Geological compilation maps of the Northern Stewart River map area, Klondike and Sixtymile districts (115N/15, 16; 115O/13, 14 and parts of 115O/15, 16). Exploration and Geological Services, Yukon, Indian and Northern Affairs Canada, Open File 1996-1(G), 1:50 000 scale.

Mosley M.P. and Schumm, S.A., 1977. Stream junctions – a probable location for bedrock placers. Economic Geology, vol. 72, p. 691-697.

Rushton, R.W., Nesbitt, B.E., Muehlenbachs, K. and Mortensen, J.K., 1993. A fluid inclusion and stable isotope study of Au quartz veins in the Klondike district, Yukon Territory, Canada: a section through a mesothermal vein system. Economic Geology, vol. 38, p. 647-678.

Schoch, R.M., 1989. Stratigraphy: principle and methods. Van Nostrand Reinhold, New York, 375 p.

Slingerland, R., 1984. Role of hydraulic sorting in the origin of fluvial placers. Journal of Sedimentary Petrology, vol. 54, p. 137-150.

Tempelman-Kluit, D.J., 1980. Evolution of physiography and drainage in southern Yukon. Canadian Journal of Earth Sciences, vol. 17, p. 1189-1203.

Vernon, P. and Hughes, O.L., 1966. Surficial geology, Dawson, Larsen Creek, and Nash Creek map areas, Yukon Territory (116B and 116B E, 116A and 106D). Geological Survey of Canada, Bulletin 136, 25 p.

Lithogeochemistry of meta-volcanic rocks from Yukon-Tanana Terrane, Finlayson Lake region, Yukon: Preliminary results

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Piercey, S.J., Hunt, J.A. and Murphy, D.C., 1999. Lithogeochemistry of meta-volcanic rocks from Yukon-Tanana Terrane, Finlayson Lake region, Yukon: Preliminary results. *In:* Yukon Exploration and Geology 1998, C.F. Roots and D.S. Emond (eds.), Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 125-138.

ABSTRACT

In this paper, we present a preliminary assessment of the lithogeochemical characteristics of meta-volcanic rocks in the Finlayson Lake region. Unit 2 mafic meta-volcanic rocks are subdivided into three suites: 1) low Ti tholeiites and boninites (suite 2a); 2) transitional (oceanic island basalt, OIB?), Light Rare Earth Element (LREE) -enriched tholeiites (suite 2b); and 3) normal mid-ocean ridge basalts (suite 2c; N-MORB). Suite 2a has similarities to rocks formed in ancient suprasubduction zone ophiolites and in forearcs in modern intraoceanic arcs. Unit 3 felsic meta-volcanic rocks comprise two subdivisions: 1) a low Eu/Eu*, Zr/Y, and Ce/Yb_N suite (3a); and 2) a higher Eu/Eu*, Zr/Y and Ce/Yb_N suite (3b). All unit 3 felsic meta-volcanic rocks have calc-alkalic continental arc signatures. Meta-basaltic rocks of the Campbell Range belt (CRB) fall into three suites: 1) moderately LREE enriched E-MORB type rocks (CRB_1); 2) LREE depleted N-MORB type rocks (CRB_2); and 3) a high Mg#, High Field Strength Elements (HFSE) and LREE-enriched tholeiitic suite (CRB_3). All CRB meta-basaltic rocks have features consistent with generation in an ocean basin and/or back-arc/marginal basin setting. The most prospective suites for volcanogenic massive sulphide mineralization in the Finlayson Lake region are 2a, 3a, and CRB_1 and CRB_2.

RÉSUMÉ

Dans cette étude, on présente une évaluation préliminaire des caractéristiques lithogéochimiques des roches métavolcaniques de la région du lac Finlayson. Les roches métavolcaniques mafiques de l'unité 2 sont subdivisées en trois ensembles : 1) tholéiites et boninites à faible teneur en Ti (2a); 2) roches de transition (basalte d'île océanique, OIB?), tholéiites enrichies en éléments de terres rares légers (LREE; 2b); et 3) basaltes normaux de dorsale médio-océanique (2c; N-MORB). L'ensemble 2a présente des similitudes avec les roches formées dans les anciennes ophiolites de zone de suprasubduction et dans les avant-arcs d'arcs intraocéaniques modernes. Les roches métavolcaniques de l'unité 3 sont subdivisées en deux : 1) un ensemble à faibles rapports Eu/Eu*, Zr/Y, et Ce/Yb_N (3a); et 2) un ensemble à rapports Eu/Eu*, Zr/Y et Ce/Yb_N plus élevés (3b). Toutes les roches métavolcaniques felsiques de l'unité 3 présentent des signatures calco-alcalines d'arc continental. Les roches métabasaltiques de la zone de la chaîne Campbell (CRB) se répartissent en trois ensembles : 1) roches de type E-MORB modérément enrichies en LREE (CRB_1); 2) roches de type N-MORB appauvries en LREE (CRB_2); et 3) un ensemble tholéiitique à forte teneur en Mg#, dont les roches sont enrichies en HFSE et en LREE (CRB_3). Toutes les roches métabasaltiques CRB présentent des caractéristiques conformes à celles des roches formées dans un cadre de bassin océanique et/ou de bassin arrière-arc/marginal. Dans la région du lac Finlayson, les ensembles les plus prometteurs quant à la minéralisation en sulfures massifs d'origine volcanique sont les 2a, 3a, et CRB_1 et CRB_2.

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INTRODUCTION

Any appreciation of the geological controls on mineral deposits relies heavily on an acute knowledge of the stratigraphic and geodynamic setting in which mineral deposits occur. It has been shown from numerous examples that the tectonic setting of a mineral deposit often plays a strong control on the nature, style, and distribution of that mineral deposit type, both in space and time (e.g., Barley and Groves, 1992; Kerrich and Wyman, 1996,1997). In particular, various studies have illustrated that many volcanogenic massive sulphide (VMS) occurrences have specific tectonic settings (and subsets of these settings), and their genesis is related to the petrotectonic processes related to these settings (e.g., Franklin et al., 1981; Lesher et al., 1986; Swinden, 1991; Barrie et al., 1993; Kerrich and Wyman, 1996, 1997; Lentz, 1998). The recent discoveries of VMS deposits and occurrences (e.g., Kudz Ze Kayah, Wolverine Lake, Fyre Lake, Ice, Money; Fig. 1) has prompted the Yukon Geology Program (and collaborators) to seek a better understanding of the geological and geodynamic controls on this mineralization in the Finlayson Lake area, including: 1:50 000-scale regional mapping (Murphy and Timmerman, 1997; Murphy, 1997, 1998; Hunt and Murphy, 1998; Murphy and Piercey, this volume), mineral deposit studies (Hunt, 1997, 1998a,b), and lithogeochemical studies (Sebert and Hunt, this volume; this study).

In this paper we present preliminary chemostratigraphic information on meta-volcanic rocks in the Finlayson Lake area to provide a preliminary overview and interpretation of the petrotectonic affinity and evolution of the Yukon-Tanana Terrane and contained VMS mineralization. The specific signatures of given deposits or occurrences are not given but the implications of these preliminary results to VMS exploration in this region are discussed.

STRATIGRAPHIC SETTING OF SAMPLES

Yukon-Tanana Terrane in the Finlayson Lake massive sulphide belt comprises complexly deformed and metamorphosed sedimentary, volcanic and plutonic rocks (Tempelman-Kluit, 1979; Mortensen and Jilson, 1985; Mortensen, 1992; Murphy,

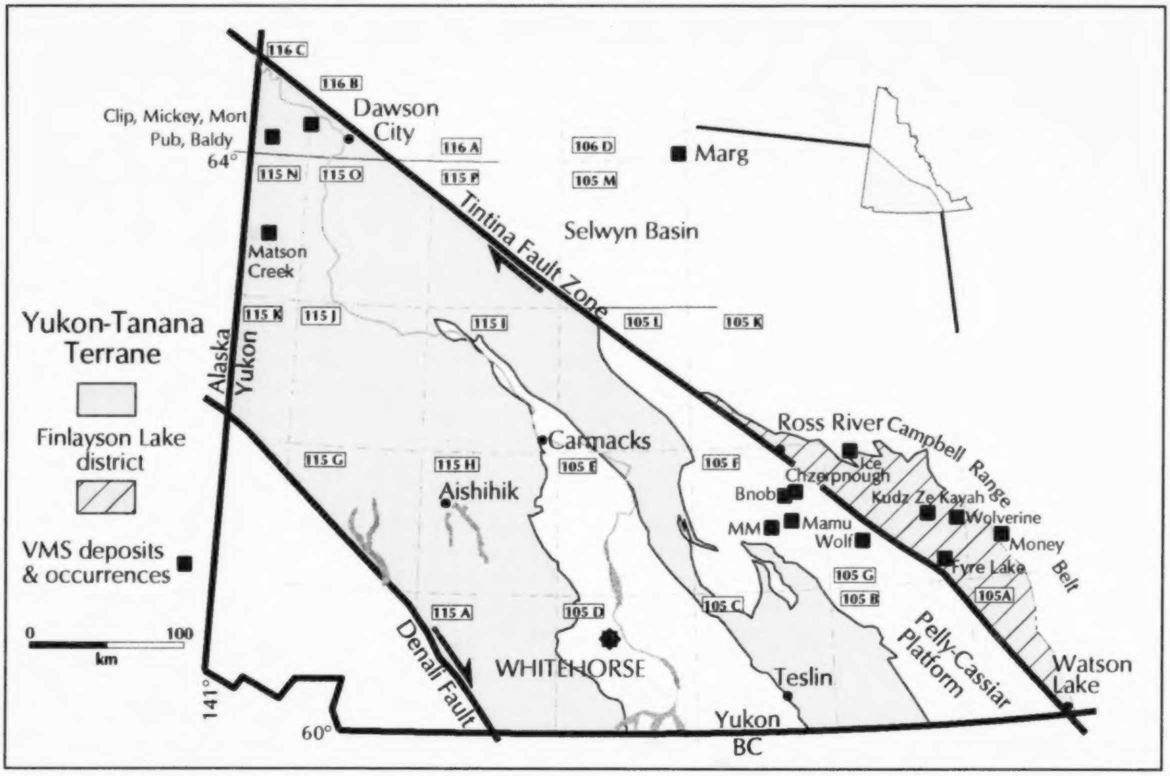

116 C
116 B
Dawson City
Clip, Mickey, Mort
Pub, Baldy
64°
116 A
106 D
Marg
115 N
115 O
115 P
105 M
Tintina Fault Zone
Selwyn Basin
Matson Creek
Yukon-Tanana Terrane
115 K
115 J
115 I
105 L
105 K
Alaska
Yukon
Finlayson Lake district
VMS deposits & occurrences
Ross River
Campbell Range
Ice
Chzerpnough
Bnob
Kudz Ze Kayah
Wolverine
Mamu
MM
Wolf
Money
Fyre Lake
Belt
Carmacks
115 G
115 H
105 E
105 F
Aishihik
105 G
105 B
105A
115 A
105 D
105 C
Pelly-Cassiar Platform
Denali Fault
WHITEHORSE
Teslin
Watson Lake
0
100
km
141°
60°
Yukon
BC

Figure 1. Location of the Finlayson Lake district and related volcanogenic massive sulphide deposits/occurrences in relation to the distribution of Yukon-Tanana Terrane in the Yukon (Modified from Wheeler and McFeely, 1991).

1998). Based on 1:50 000-scale geological mapping, Murphy (1998) and Murphy and Piercey (this volume) outlined a stratigraphic framework for this part of Yukon-Tanana Terrane and placed the syngenetic mineral occurrences within this framework. Figure 2 schematically shows the stratigraphy for this area (units 1-7 and Campbell Range belt).

Meaningful conclusions from geochemical data on complexly deformed and metamorphosed rocks requires a knowledge of the stratigraphic position and protoliths of the rocks. We selected 41 samples that were either of clearly igneous origin, or that are reasonably well constrained as to have an igneous protolith. These data presented here include chloritic schist and metabasitic rocks of unit 2 from the Grass Lakes map area (Murphy, 1998) and the Fire Lake area (Hunt and Murphy, 1998), felsic meta-volcanic rocks from unit 3 (host of the Kudz Ze Kayah deposit), Simpson Range plutonic suite (SRPS), and mafic meta-volcanic rocks from the Campbell Range belt (those that host the Ice deposit and Money occurrence). This preliminary dataset does not contain unit 2 rocks from the area adjacent to the Fyre Lake deposit; those rocks are discussed in Sebert and Hunt (this volume), and lithogeochemical samples from units 4-7 that were collected during 1998 and remain to be investigated.

GEOCHEMISTRY OF META-VOLCANIC ROCKS

Samples were analyzed for major, trace, and rare-earth elements (REE) at Activation Laboratories in Ancaster, Ontario. Major elements were analyzed on fused discs by X-ray fluorescence, while trace elements and REE were analyzed by research-grade inductively coupled plasma mass spectrometry (ICP-MS). Figures 3-8 summarize the analytical data, plotted on both discrimination diagrams and primitive-mantle/chondrite-normalized plots. Complete data are not presented in this paper (Tables 1-3) but will be published in forthcoming papers; representative data for each suite can be obtained from the authors upon request.

It should be noted that most of the rocks from the Finlayson Lake region have been affected by greenschist to amphibolite facies metamorphism, and some have also experienced hydrothermal alteration. This restricts which elements can be used for conventional rock and tectonic classifications (e.g., total alkalis versus silica plots). Most major elements, with the exceptions of Al_2O_3 and TiO_2, are considered partly mobile during alteration and metamorphism (Rollinson, 1993). Major

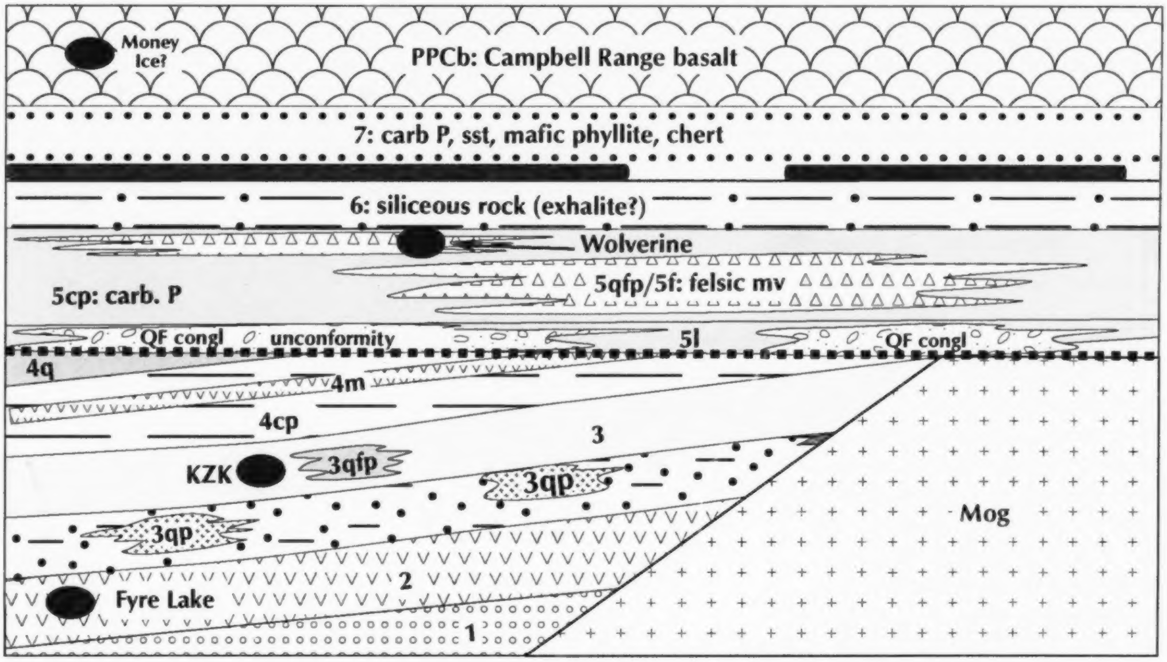


Figure 2. The stratigraphy and distribution of volcanogenic massive sulphide mineralization in the Finlayson Lake district. Units are defined in Murphy and Piercey (this volume).

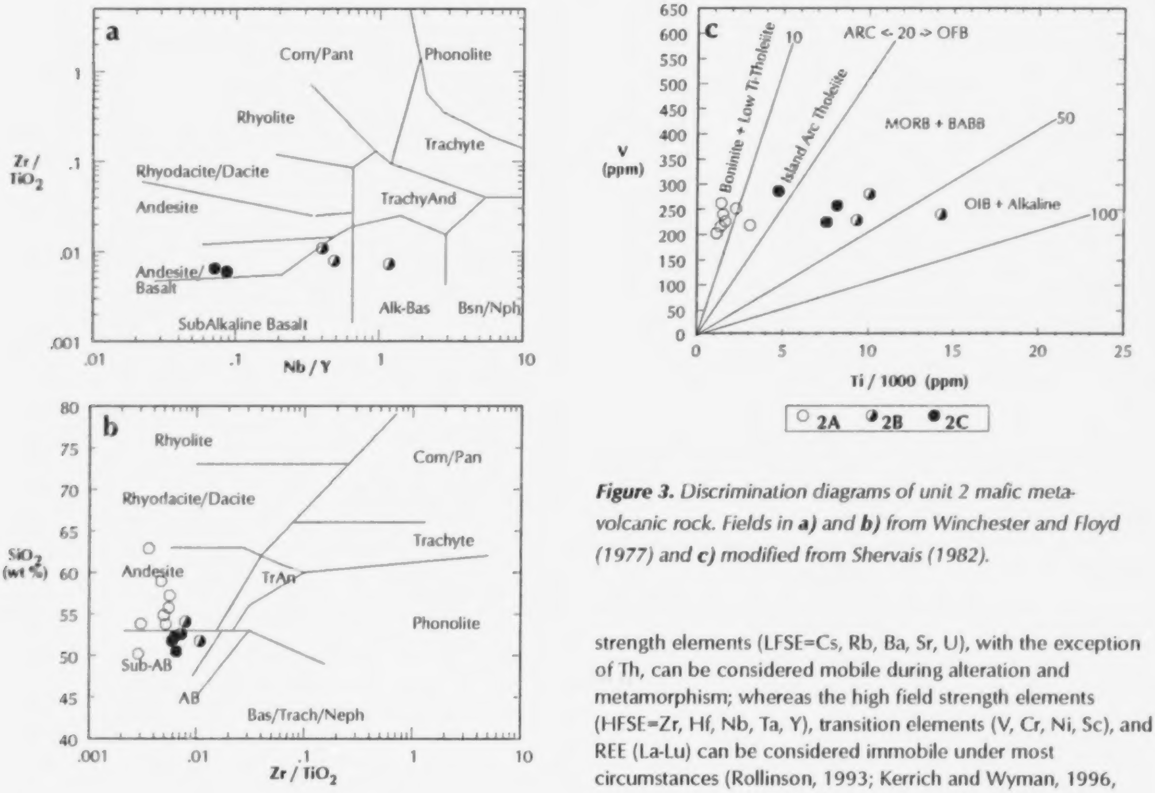


*Figure 3. Discrimination diagrams of unit 2 mafic metavolcanic rock. Fields in **a)** and **b)** from Winchester and Floyd (1977) and **c)** modified from Shervais (1982).*

***Table 1.** Selected elemental concentrations and ratio ranges for unit 2 mafic metavolcanic rocks. Values in brackets are the average values. SiO_2 and TiO_2 are given as weight percent oxides (wt%); Zr, Nb, Ni and Cr are in parts per million (ppm).*

Subgroup	2A	Average	2B	Average	2C	Average
Mg#	48.37-73.69	(65.41)	52.73-69.32	(55.88)	52.82-59.17	(55.93)
SiO_2	47.17-61.25	(53.78)	47.98-50.16	(49.23)	46.09-50.47	(48.51)
TiO_2	0.17-0.89	(0.36)	1.49-2.21	(1.74)	0.76-1.32	(1.07)
Ce/Yb_N	0.66-1.60	(1.08)	7.39-11.86	(10.10)	1.64-2.15	(1.96)
Zr/Y	1.13-2.08	(1.57)	4.63-6.48	(5.36)	2.09-3.07	(2.67)
Zr	8-25	(14)	111-274	(149)	48-86	(67)
Nb	< LD		(10-28)	(18)	(0-2.0)	(1)
Ni	30-259	(133)	0-89	(47)	32-85	(45)
Cr	12-855	(324)	0-211	(185)	61-238	(133)

element plots are nevertheless shown for descriptive purposes because in many cases the data for each suite cluster together (e.g., Zr/TiO_2 -SiO_2 Figs. 3, 5, 7) and are considered to be close to original compositions. Furthermore, Mg#'s [(Mg/Mg+Fe)•100] appear to be relatively undisturbed except where rocks have been affected by alteration at high water-rock ratios (Dunning et al., 1991). In terms of trace elements, most of the low field strength elements (LFSE=Cs, Rb, Ba, Sr, U), with the exception of Th, can be considered mobile during alteration and metamorphism; whereas the high field strength elements (HFSE=Zr, Hf, Nb, Ta, Y), transition elements (V, Cr, Ni, Sc), and REE (La-Lu) can be considered immobile under most circumstances (Rollinson, 1993; Kerrich and Wyman, 1996, 1997). The diagrams and normalized plots used in this report use immobile elements in most cases.

UNIT 2

Unit 2 of Murphy (1998) and Murphy and Piercey (this volume) can be subdivided into three geochemical suites based on their trace and major element contents (Figs. 3a and b). Figure 3a shows that the 2b and 2c suites have basaltic-andesite and transitional subalkalic basalt/alkaline basalt affinities, respectively. Owing to the low Nb content of suite 2a, it doesn't plot on Figure 3a (see Table 1); however, it ranges from subalkalic basalt to andesite on Figure 3b.

The 2a suite is characterized by low Ti/V ratios, TiO_2 (0.17-0.87%) and HFSE contents (Zr=8-25 ppm, Nb < detection) and Zr/Y ratios (1.12-2.08), yet has elevated SiO_2 (47.17-61.25%), Mg#'s (48.37-73.69), and compatible element contents (Ni=30-259 ppm; Cr=12-855 ppm; Fig. 3c, Table 1). Suite 2a is strongly depleted in total REE (1-10x chondrite), with relative LREE depletions (Ce/Yb_N=0.66-1.60; N-normalized to primitive mantle values), but some samples have slightly elevated La, leading to dish-shaped profiles (Fig. 4a). When compared to the primitive mantle, suite 2a has very low HFSE contents, (Zr, Nb, Y), and a crudely dish-shaped profile of all elements (Fig. 4b). The dish-shaped profile, low TiO_2, HFSE, and total REE contents, irregularly high transition metal contents (Ni, Cr), Mg#'s, and andesitic levels of SiO_2 are consistent with the 2a suite having a boninite to low-Ti tholeiite affinity, common to many rocks found in modern day forearcs and suprasubduction zone ophiolites (Jenner, 1981; Hickey and Frey, 1982; Crawford et al., 1989; Pearce et al., 1992; Piercey et al., 1997; Bédard et al., 1998).

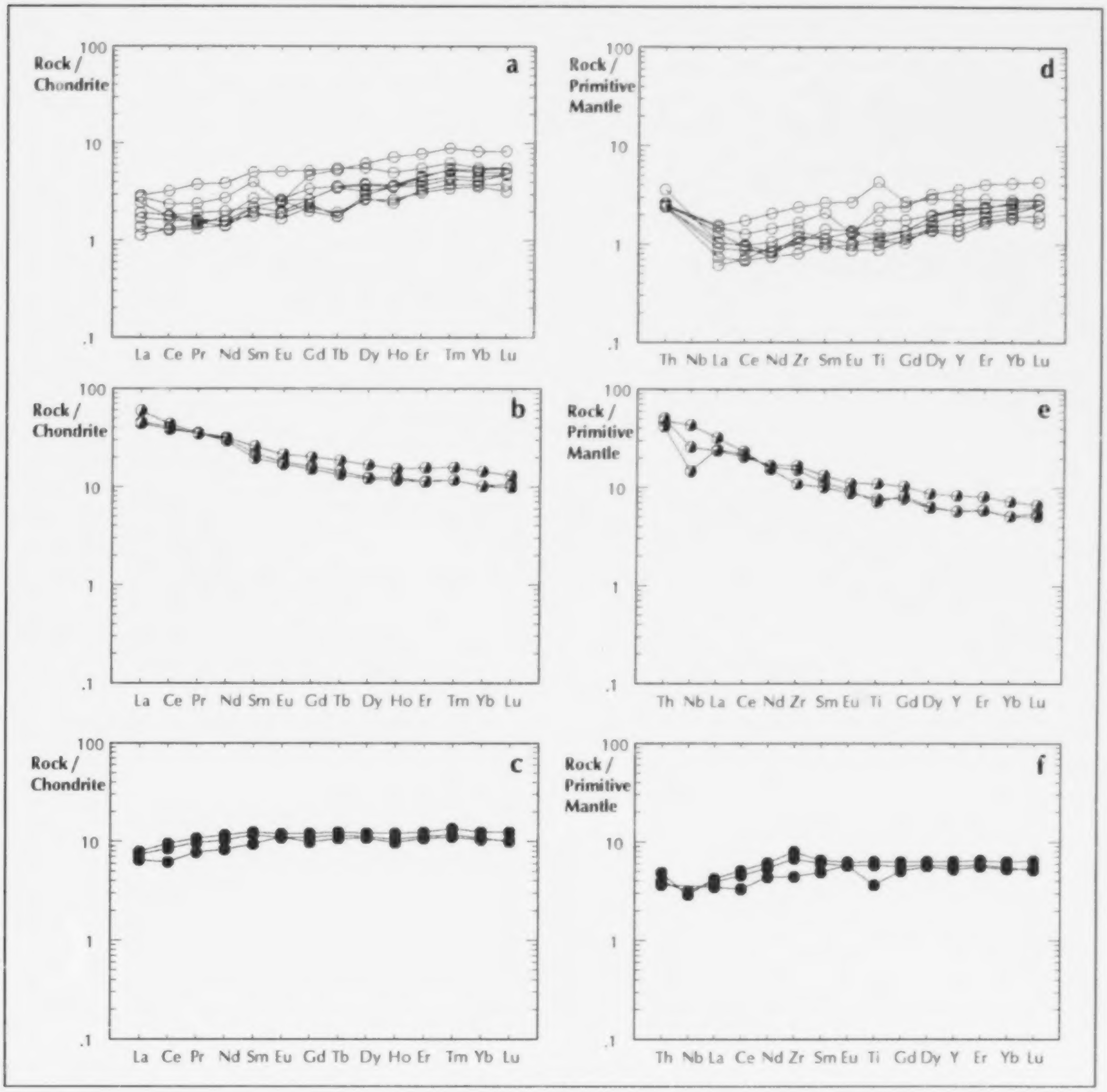


Figure 4. *Chondrite-normalized REE and primitive mantle-normalized multi-element plots for unit 2 mafic meta-volcanic rocks:* ***a)*** *and* ***d)*** *– 2a suite;* ***b)*** *and* ***e)*** *– 2b suite; and* ***c)*** *and* ***f)*** *– 2c suite. Chondrite normalization values from Taylor and McLennan (1985), and primitive mantle values from Sun and McDonough (1989).*

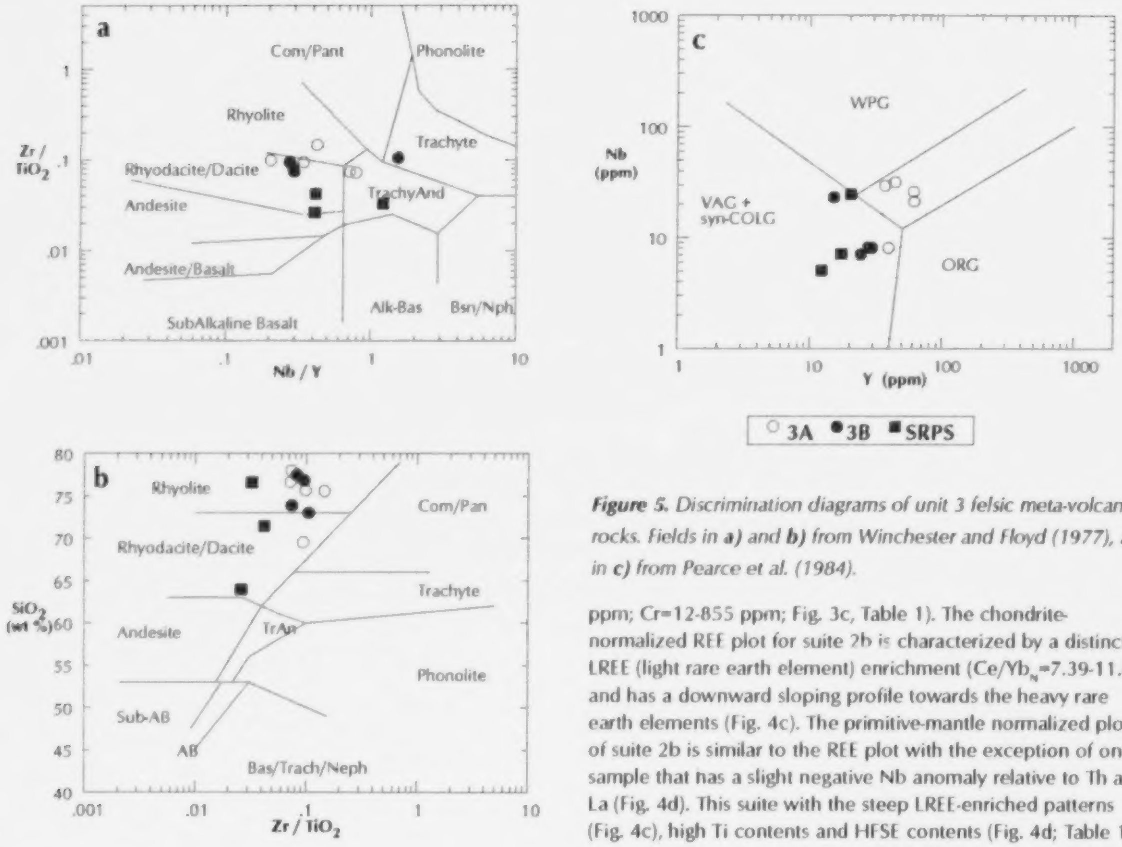


Figure 5. *Discrimination diagrams of unit 3 felsic meta-volcanic rocks. Fields in* ***a)*** *and* ***b)*** *from Winchester and Floyd (1977), and in* ***c)*** *from Pearce et al. (1984).*

Table 2. *Selected elemental concentrations and ratio ranges for unit 3 felsic meta-volcanic rocks and the Simpson Range Plutonic Suite. Values in brackets are the average values. SiO_2 , Na_2O and K_2O are given as weight percent oxides (wt%); Zr is given in parts per million (ppm).*

Subgroup	3A	Average	3B	Average	SRPS	Average
SiO_2	68.84-75.85	(72.68)	72.42-74.66	(74.97)	62.87-71.86	(68.45)
Na_2O	0.94-3.26	(1.60)	0.25-6.39	(2.87)	1.64-2.67	(2.19)
K_2O	2.96-9.65	(6.45)	0.63-7.74	(3.94)	0.94-2.44	(2.36)
Ce/Yb_N	4.45-7.46	(6.15)	5.54-20.00	(10.76)	6.92-8.51	(7.59)
Zr/Y	4.16-7.18	(5.86)	2.54-12.60	(6.47)	8.75-12/16	(9.32)
Zr	163-438	(261)	99-189	(142)	105-231	(152)
Eu/Eu*[1]	0.16-0.62	(0.34)	0.35-0.72	(0.56)	0.69-0.92	(0.80)
Ti*[2]	4.50-12.63	(8.65)	14.32-25.88	(17.22)	2.34-4.40	(3.29)

[1] $Eu/Eu^* = Eu_N / (Sm_N{}^*Gd_N)^{1/2}$; [2] $Ti^* = 0.5^* (Sm_N + Eu_N) / Ti_N$; N = normalized to primitive mantle values.

In contrast to suite 2a, suite 2b has elevated Ti/V ratios, TiO_2 (1.49-2.21%), HFSE (Zr=111-174 ppm; Nb=10-28 ppm) and Zr/Y ratios (4.63-6.48), while having lower SiO_2 (47.98-50.16%), Mg#'s (52.73-69.32), and transition metal contents (Ni=0-89 ppm; Cr=12-855 ppm; Fig. 3c, Table 1). The chondrite-normalized REE plot for suite 2b is characterized by a distinctive LREE (light rare earth element) enrichment (Ce/Yb_N=7.39-11.86) and has a downward sloping profile towards the heavy rare earth elements (Fig. 4c). The primitive-mantle normalized plot of suite 2b is similar to the REE plot with the exception of one sample that has a slight negative Nb anomaly relative to Th and La (Fig. 4d). This suite with the steep LREE-enriched patterns (Fig. 4c), high Ti contents and HFSE contents (Fig. 4d; Table 1) is consistent with rocks from enriched source regions transitional between tholeiitic and alkaline oceanic island basalts (OIB); however, the sample with low Nb relative to La and Th (Fig. 4d) suggests a possible relationship to arc magmatism (e.g., Kostopoulos and Murton, 1992).

Suite 2c has chemical affinities that are intermediate between suites 2a and 2b. Suite 2c has moderate Ti/V ratios, moderate TiO_2 (0.76-1.32%), HFSE (Zr=48-86ppm; Nb=0-2.0 ppm; Zr/Y=2.09-3.07), and Mg#'s (52.82-59.17; Fig. 3c, Table 1). Silica contents are consistent with basaltic parentage (SiO_2=46.09-50.47), and transition metal contents overlap with those of the 2b suite (Ni=32-85 ppm; Cr= 61-238 ppm). The REE character of suite 2c is presented in Fig. 4c and these rocks have relatively flat MREE (middle rare earth elements) to HREE (Sm-Lu), yet have a slight depletion of the LREE (Ce/Yb_N=1.64-2.15). The primitive-mantle normalized plot of suite 2c is similar to the REE plot; however, there is a slight negative Nb anomaly relative to Th and La, and a slight positive anomaly of Zr relative to Nd and Sm (Fig. 4c). Both of these features may reflect arc-related magmatism (slab-fluid metasomatism?), although there is some concern that the negative Nb anomaly relative to Th is an analytical artifact. The moderate Ti content, LREE-depleted nature, and moderate HFSE and transitional element contents of suite 2c are consistent with normal mid-ocean ridge basalt magmatism (N-MORB).

UNIT 3

Lithogeochemical data for unit 3 are presented in Table 2 and Figures 5 and 6. Unit 3 meta-volcanic rocks have been subdivided into two suites based on their geochemical affinities; data for the Simpson Range Plutonic Suite (SRPS) are also presented as they may be coeval with unit 3 meta-volcanic rocks (Mortensen, 1992; Grant, 1997). All of the unit 3 meta-

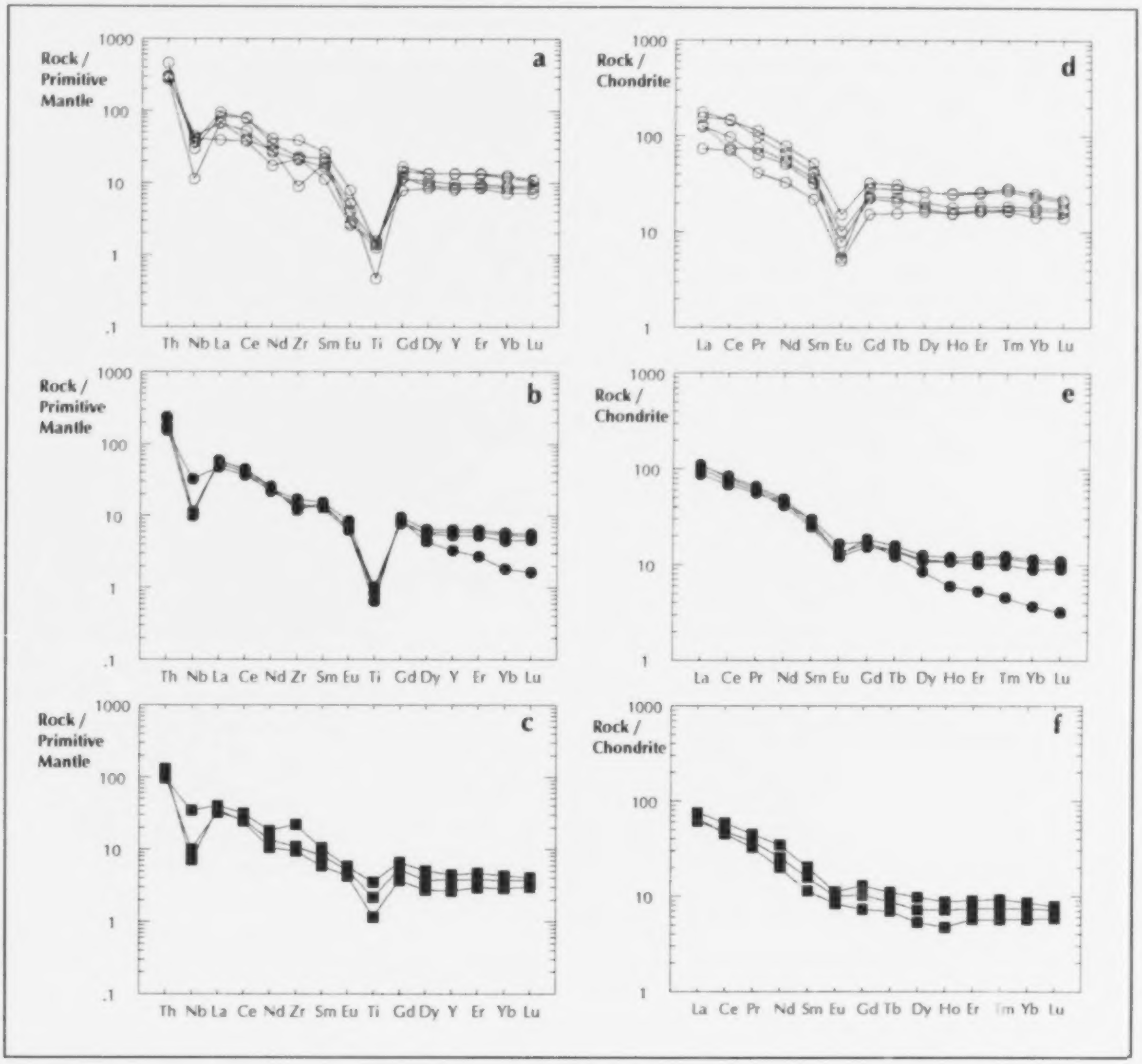


*Figure 6. Primitive mantle-normalized multi-element and chondrite-normalized REE plots for unit 3 felsic meta-volcanic rocks, including: **a)** and **d)** – 3a suite; **b)** and **e)** – 3b suite; and **c)** and **f)** – Simpson Range Plutonic Suite. Chondrite normalization values from Taylor and McLennan (1985), and primitive mantle values from Sun and McDonough (1989).*

volcanic rocks and the SRPS have broadly dacitic to rhyolitic composition with some samples exhibiting more alkaline trachyandesite to trachyte compositions (Fig. 5a-b). Felsic meta-volcanic rocks of suite 3a have broadly rhyodacitic-rhyolite to trachyandesite affinities and have characteristics akin to within-plate (rift-related) granitoids and volcanic arc granitoids (Figs. 5a-c). In contrast, the SRPS and suite 3b felsic meta-volcanic rocks have predominantly volcanic arc granitoid affinities (Fig. 5c).

Primitive-mantle normalized plots for unit 3 felsic meta-volcanic rocks and the SRPS are given in Figures 6a to 6c. On these plots there is little difference between the three groupings. All are characterized by weak to very strong negative Nb anomalies relative to Th and La (arc signature), have gently downward trending profiles from the LREE/LFSE to the HREE/HFSE, and all exhibit variably negative Ti relative to meta-volcanic and metaplutonic rocks with calc-alkalic continental arc affinities.

Although there is a cursory similarity between the three groupings, there are differences. For instance, the chondrite-normalized REE patterns for suite 3a are characterized by relatively flat HREE profiles, slight LREE enrichments (Ce/Yb_N=4.54-7.46), a very strong negative Eu anomaly (Eu/Eu^*=0.16-0.62), moderately high Ti^* (4.50-12.63) and Zr values (163-438 ppm), yet they exhibit the lowest Zr/Y values (4.16-7.18; Figs. 6a and 6d; Table 2). In contrast, suite 3b is characterized by steep chondrite-normalized REE patterns (Ce/Yb_N=5.54-20.00), moderately negative Eu anomalies (0.35-0.75), moderate Zr contents (99-189 ppm), relatively low Zr/Y ratios (2.54-12.60), and very high Ti^* values (14.32-25.88; Figs. 6b and 6e; Table 2). The SRPS is somewhat different than unit 3 meta-volcanic rocks in having the highest TiO_2 content (Ti^*=2.34-4.40), having moderate LREE enrichment (Ce/Yb_N=6.92-8.51), a slight negative Eu anomaly (Eu/Eu^*=0.69-0.92), while having moderate Zr (195-231 ppm) and high Zr/Y (8.75-12.16; Figs. 6c and 6f, Table 2).

All three felsic groupings are characterized by high to very high silica (62.87-75.85%; Table 2), with the SRPS having the lowest SiO_2 contents (62.87-71.86%) and moderate Na_2O (1.64-2.67) and K_2O (0.94-2.44). Suite 3a is characterized by high SiO_2 (68.84-75.85%) and low Na_2O (0.94-3.26%) and high K_2O (2.96-9.65%), while suite 3b has higher Na_2O (0.25-3.69%) and lower K_2O (0.63-7.74%) than suite 3a (Table 2). The highly variable Na_2O and K_2O in the aforementioned suites may be a function of variable alteration and mobility of elements during hydrothermal alteration.

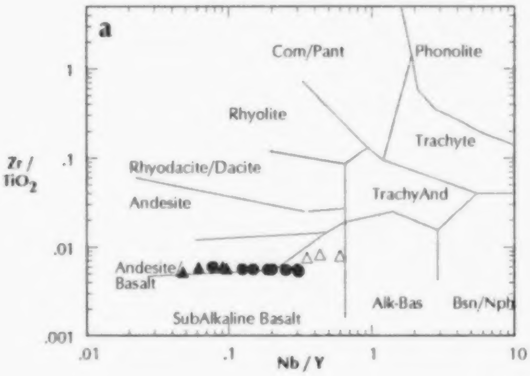
CAMPBELL RANGE BELT

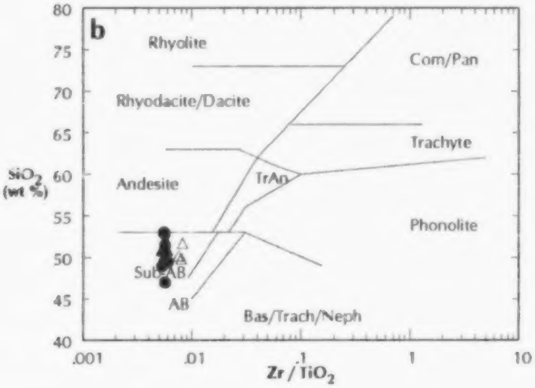
Mafic meta-volcanic rocks from the Campbell Range belt (CRB) are much less ambiguous with respect to their origin when compared to the chloritic schists of unit 2. Most of these rocks are pillowed and massive lavas, interbedded with lesser volcaniclastic and epiclastic rocks, and locally chert and marble (e.g., Murphy and Piercey, this volume; Plint and Gordon, 1997). Our preliminary data show that the CRB meta-volcanic rocks are basaltic-andesite to subalkaline basalt (Fig. 7a-b) and have moderate Ti/V ratios consistent with eruption in an ocean floor or marginal basin setting (Fig. 7c; cf. Nelson, 1993; Plint and Gordon, 1997).

Three subdivisions of the CRB meta-basalt are proposed based on their trace element chemistry. The first subdivision, CRB_1, is characterized by moderate Ti/V ratios, TiO_2 (1.08-1.86%), HFSE contents (Zr=61-104 ppm; Nb=2-10 ppm), Zr/Y ratios (2.51-3.15), moderate transition metal contents (Ni=0-118 ppm; Cr=36-402 ppm) with slightly to well fractionated Mg#'s (51.37-65.84; Fig. 7, Table 3). The REE profiles for the CRB_1 suite are relatively flat with flat to slightly enriched LREE abundances (Ce/Yb_N=0.98-1.77; Fig. 8a). The primitive mantle-normalized multi-element plot for the CRB_1 suite has a relatively flat to slightly enriched character, with one sample having very low Nb contents (Fig. 8d).

The CRB_2 suite is chemically similar to the CRB_1 suite: SiO_2 (47.72-49.41%), TiO_2 (0.84-2.17%), Ti/V ratios, Zr (44-130 ppm), Nb (1-4 ppm), transitional metal contents (Ni=0-105 ppm; Cr= 60-282 ppm), and Zr/Y ratios (2.10-2.95; Fig. 7c, Table 3). Magnesium numbers for suite CRB_2 are lower and more fractionated than suite CRB_1 (45.81-59.30), and the major difference between CRB_1 and CRB_2 lies in their REE chemistry, as suite CRB_2 has quite a strong LREE depletion (Ce/Yb_N=0.84-2.17; Fig. 8b). The primitive-mantle-normalized plot for suite CRB_2 is also somewhat different, with two samples having low Nb relative to Th and La, consistent with arc-like rocks (Fig. 8e). However, the relative imprecision of the Th analyses makes any interpretation of arc influence somewhat tentative. Based on the aforementioned characteristics, suite CRB_1 has geochemical characteristics consistent with enriched mid-ocean ridge basalts (E-MORB); while the LREE depleted nature of suite CRB_2 is consistent with N-MORB parentage.

The CRB_3 suite has a different signature relative to the CRB_1 and CRB_2 suites. Although having similar SiO_2 and Zr contents (49.84-51.68% and 65-89 ppm, respectively), suite CRB_3 is characterized by lower TiO_2 (0.86-1.12) and Ti/V ratios, high and only slightly fractionated Mg#'s (61.07-71.11). It also has higher Nb (5.8-11.2 ppm), Ni (65-170 ppm), Cr contents (224-586 ppm), and Zr/Y ratios (3.95-4.77; Fig. 7c, Table 3). The REE pattern for suite CRB_3 is also different, characterized by a very steep, LREE enriched pattern (Ce/Yb_N=2.83-3.56), which decreases downward toward the HREE end (Fig. 8c). The primitive-mantle-normalized plot is similar with steep downward trends towards the HREE/HFSE end of the diagrams (Fig. 8d). Suite CRB_3 has some characteristics, at least in terms of their REE, to suite 2b; however, there are some major differences. Suite CRB_3 has lower average TiO_2, higher Mg#'s, lower total REE and





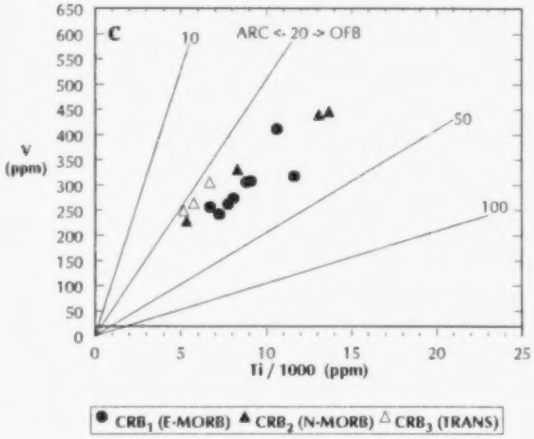


Figure 7. *Discrimination diagrams of the Campbell Range belt mafic meta-volcanic rock. Fields in* ***a)*** *and* ***b)*** *from Winchester and Floyd (1977), and in* ***c)*** *modified from Shervais (1982).*

Table 3. *Selected elemental concentrations and ratio ranges for the Campbell Range belt mafic meta-volcanic rocks. Values in brackets are the average values.*

Subgroup	CRB_1	Average	CRB_2	Average	CRB_3	Average
Mg#	51.37-65.84	(57.68)	45.81-59.30	(52.02)	61.07-71.11	(66.32)
SiO_2	42.69-50.63	(47.64)	47.72-49.41	(48.53)	49.84-51.68	(50.57)
TiO_2	1.08-1.86	(1.39)	0.84-2.17	(1.61)	0.86-1.12	(0.98)
Ce/Yb_N	0.98-1.77	(1.28)	0.84-2.17	(0.78)	2.83-3.56	(3.12)
Zr/Y	2.51-3.15	(2.74)	2.10-2.95	(2.51)	3.95-4.77	(4.30)
Zr	61-104	(77.63)	44-130	(93.75)	65-89	(77.67)
Nb	2-10	(5.75)	1-4	(2.75)	5.8-11.2	(8.40)
Ni	0-118	(62)	0-105	(35)	65-170	(131)
Cr	36-402	(263)	60-282	(151)	224-586	(445)

HFSE contents (Figs. 4b, 4e, 8c and 8f; Tables 1 and 2). These rocks are typed as LREE-enriched tholeiites and are somewhat transitional between arc and non-arc affinities (Fig. 7c); these characteristics will be addressed in the discussion.

DISCUSSION: SIGNIFICANCE OF GEOCHEMICAL DATA AND EXPLORATION IMPLICATIONS

The meta-volcanic rocks from the Finlayson Lake region have been subdivided into geochemical suites with a wide range of lithogeochemical signatures. However, certain consistencies arise between each of the stratigraphic units and these consistencies have implications for metallogenic models for the YTT in this region.

UNIT 2 MAFIC META-VOLCANIC ROCKS

The low-Ti rocks in unit 2 (suite 2a) are chemically similar to rocks found in forearc regions of both modern and ancient intraoceanic arc environments (Crawford et al., 1989; Pearce et al., 1992; Bloomer et al., 1995; Piercey et al., 1997; Bédard et al., 1998; Giaramita et al., 1998). The co-existence of suite 2a boninitic rocks with N-MORB (2c) and transitional tholeiitic (2b) rocks in unit 2 may seem somewhat disconcerting considering the latters' similarities to many ocean/back-arc basin environments; however, both MORB- and OIB-like magmatism have been documented together in arc environments (e.g., Coish et al., 1982; Johnson and Fryer, 1990; Kostopoulos and Murton, 1992; Piercey et al., 1997; Giaramita

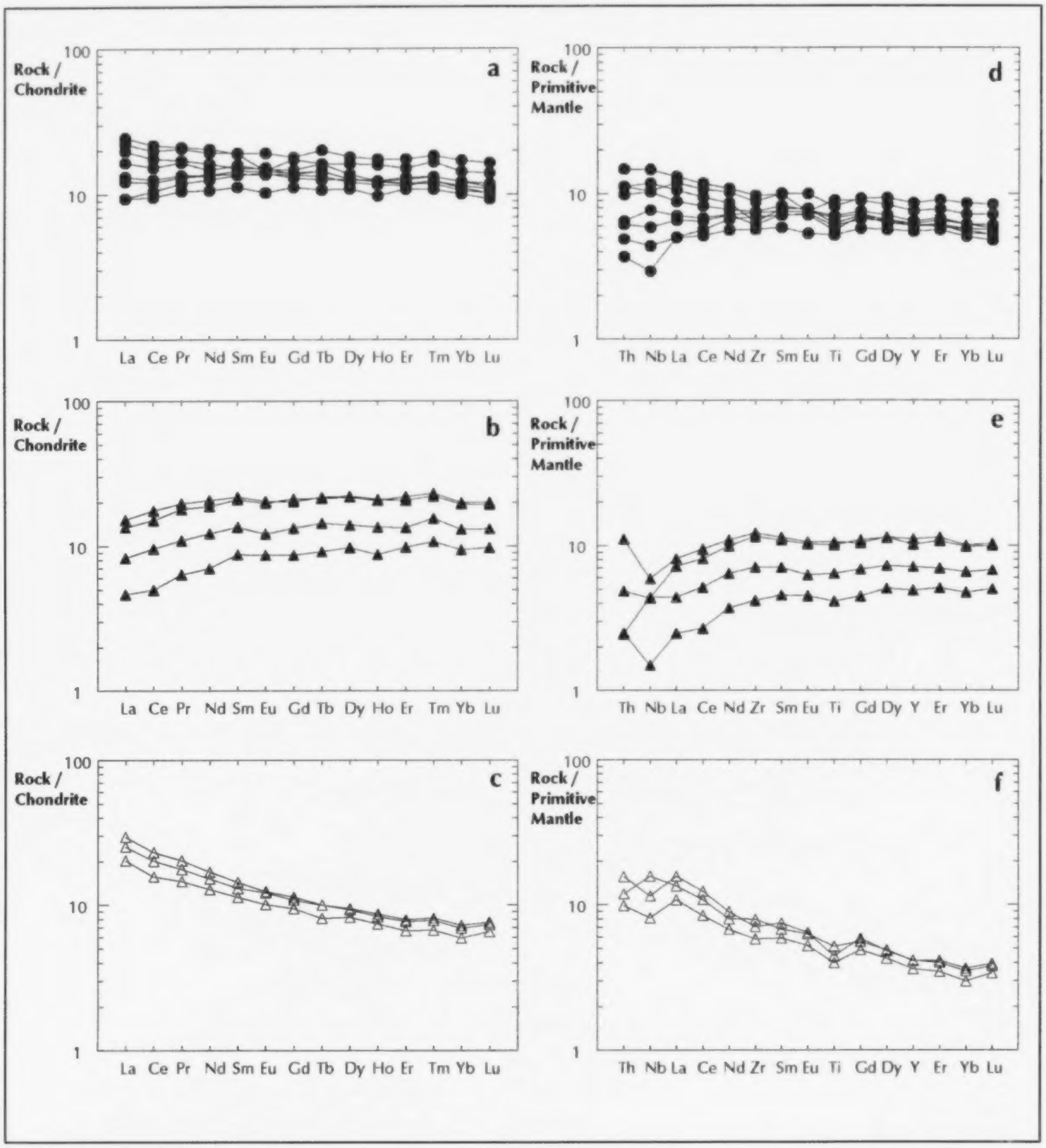


Figure 8. *Chondrite-normalized REE and primitive-mantle-normalized multi-element plots for the Campbell Range belt mafic metavolcanic rocks:* ***a)*** *and* ***d)*** *- CRB$_1$ suite;* ***b)*** *and* ***e)*** *- CRB$_2$ suite; and* ***c)*** *and* ***f)*** *- CRB$_3$ suite. Chondrite normalization values from Taylor and McLennan (1985) and primitive mantle values from Sun and McDonough (1989).*

et al., 1998). These non-arc signatures may be a function of intra-arc or back-arc basin formation (e.g., Coish et al., 1982), forearc rifting/spreading (Bédard et al., 1998), and/or OIB and/or MORB source components involved in arc-tholeiite genesis (e.g., Faloon and Crawford, 1991; Kostopoulos and Murton, 1992). Clearly, our present low level of understanding of the region precludes inferences about any of the above processes; however, this will be a focus of our continuing research.

Unit 2 hosts volcanogenic massive sulphide mineralization near Fire Lake (Fyre Lake deposit). All three suites of mafic meta-volcanic rocks in unit 2 occur at Fyre Lake and it is not clear if mineralization is preferentially associated with a specific suite (see Sebert and Hunt, this volume). Petrological processes typically associated with this type of magmatism provide a rationale for this association. The low-Ti tholeiitic and boninitic rocks are likely melts of a mantle source from which at least one MORB-type melt has been previously extracted (e.g., Hickey and Frey, 1982; Crawford et al., 1989; Pearce et al., 1992). This in itself imparts a requirement for high-heat flow in order to induce a second melting (e.g., ~1200-1300°C; Umino and Kushiro, 1989), which could act as the heat source for driving a hydrothermal system (cf. Swinden, 1991, 1996; Piercey et al., 1997). Furthermore, an extensional stress regime is a requirement for models for both boninite genesis in the plate overlying the subduction zone (Stern and Bloomer, 1992) and the genesis of MORB and transitional lavas in intra-arc/back-arc settings; such extensional regimes would provide the needed ground preparation required for the percolation of hydrothermal fluids. Although all unit 2 suites have potential to host VMS mineralization, we suggest that rocks of 2a suite are the most prospective due to the required high heat flow and extensional stress required in their formation.

UNIT 3 FELSIC META-VOLCANIC ROCKS

Unit 3 felsic meta-volcanic rocks have broadly calc-alkalic continental arc signatures; however, there are marked differences between the two sub-suites. The subtle divergence in the chemistry of the two felsic meta-volcanic suites and the SRPS is likely a function of the nature of melting. The flat HREE, low Zr/Y and Ce/Yb_N ratios, and relatively high Zr contents of suite 3a (Table 2, Fig. 6) are all features consistent with melting of a source in which amphibole or garnet was not stable (or fractionated out en-route to the surface; Rollinson, 1993; Lentz, 1998). Furthermore, the very low Eu contents (Eu/Eu* in Table 2, Fig. 6d) suggest either plagioclase fractionation en-route to their present position, or plagioclase as a restite phase in the source region (e.g., Campbell et al., 1982; Lesher et al., 1986; Barrie et al., 1993; Lentz, 1998). In contrast to suite 3a, suite 3b and SRPS show very minimal Eu anomalies and have higher Eu/Eu* values (Fig. 6, Table 2) suggesting that plagioclase fractionation has not been as important as in suite 3a. Furthermore, the steeper total REE patterns and HREE distribution, coupled with higher Zr/Y ratios are consistent with melting in a source whereby amphibole (± garnet) was stable as a restite phase, or was fractionated en-route to the surface (e.g., Lentz, 1998).

Suite 3a has a number of similarities to felsic meta-volcanic rocks in many world-class volcanogenic massive sulphide camps. For instance, Campbell et al. (1982), Lesher et al. (1986) and Barrie et al. (1993) showed that ore-bearing Archean felsic volcanics in the Superior Province (and the Abitibi Belt of the latter) had signatures with low La/Yb_N ($\sim Ce/Yb_N$), Zr/Y and Eu/Eu* values and suggested that this signature was a function of shallow-level fractionation in subvolcanic sills and magma chambers (e.g., suite 3a). In contrast, ore-barren or weakly mineralized rocks had higher La/Yb_N, Zr/Y and Eu/Eu* values. They attributed this signature to magma generation at deeper depths with lesser subvolcanic chamber fractionation (op cit; e.g., suite 3b and SRPS). Similarly, Lentz (1998), in a detailed petrotectonic study of Phanerozoic VMS camps worldwide, also showed a similar distribution of La/Yb_N, Zr/Y and Eu/Eu* distributions.

We suggest that although all of the felsic volcanic rocks have the potential to host mineralization, suite 3a is the most prospective on a regional scale. Our reasons for this arise primarily from the petrological characteristics. In particular, the evidence for shallow-level genesis and fractionation in suite 3a suggests that they are likely associated with shallow-level subvolcanic intrusions. This itself provides a potential heat source to drive hydrothermal circulation cells required to form related VMS deposits (e.g., Campbell et al., 1981; Galley, 1995, 1996). Furthermore, the chemical signature of suite 3a also suggests an extensional setting (e.g., Fig. 5c) and this may have resulted in ground preparation required for VMS formation (for details see Lentz, 1998).

CAMPBELL RANGE BELT META-BASALT

The geochemistry of Campbell Range belt meta-basalt is consistent with generation in an ocean basin (and/or back-arc/marginal) basin environment (e.g., Plint and Gordon, 1997; this study). The three different suites in the CRB likely represent varying degrees of depleted mantle (CRB_1) versus plume/hot spot influence (CRB_2 and CRB_3). The typical N-MORB chemistry of suite CRB_1 is consistent with its formation from a depleted mantle source (McKenzie and Bickle, 1988); whereas, the progressive LREE and LFSE enrichments in the CRB_2 and CRB_3 suites indicate increased plume- (OIB-like) type mantle being involved in their genesis (e.g., Langmuir et al., 1992).

VMS mineralization in the CRB is associated with generic MORB-type magmatism; no distinctive chemical signature is apparent. This association is not unreasonable considering that temperatures associated with this type of magmatism are likely on the order of 1300-1500°C (McKenzie and O'Nions, 1991; Langmuir et al., 1992). Furthermore, spreading centres associated with the aforementioned magmatism would provide fractures and faults that could act as conduits for hydrothermal fluids. In contrast, suite CRB_3 likely represents off-axis magmatism, and in contrast, would have lower heat flow and likely be displaced from favourable conduits for upwelling (and downwelling) hydrothermal fluids. Hence, we suggest that suites CRB_1 and CRB_2 are the most prospective hosts within the CRB from a regional exploration program viewpoint.

SUMMARY AND CONCLUSIONS

The preliminary work presented in this paper illustrates the chemostratigraphic complexity that exists in Yukon-Tanana Terrane of the Finlayson Lake region. The key preliminary findings of our research include:

1) Unit 2 mafic meta-volcanic rocks consist of three suites: a) a low Ti tholeiitic to boninitic suite (2a); b) a transitional (OIB) tholeiite suite (2b); and c) and N-MORB suite (2c). These suites have signatures consistent with formation in an island arc setting, similar to forearcs in the modern southwest Pacific (e.g., Bonin-Marianas, Tonga-Kermadec). Suite 2a meta-volcanic rocks are likely the most prospective hosts for VMS mineralization as they are associated with high heat flow and extensional stress (rifting?) regimes.

2) Unit 3 felsic meta-volcanic rocks and coeval plutonic rocks of the Simpson Range Plutonic Suite have calc-alkalic continental arc signatures. The meta-volcanic rocks can be divided into two suites: a) a low Ce/Yb_N, Zr/Y and Eu/Eu* suite (3a); and 2) a higher Ce/Yb_N, Zr/Y, and Eu/Eu* suite (3b). Suite 3a is likely the most prospective for volcanogenic massive sulphide mineralization as it exhibits evidence for generation at shallow crustal levels and shallow-level crystal fractionation, possibly in subvolcanic intrusive complexes. Shallow-level intrusions would provide the necessary heat pumps required for hydrothermal fluid circulation and VMS genesis (e.g., Campbell et al., 1981; Galley, 1996).

3) The Campbell Range belt contains three suites, all of which appear to be of ocean basin and/or marginal (back-arc?) basin affinity: a) a slightly LREE-enriched suite of enriched mid-ocean ridge basalts (CRB_1); b) a suite of normal mid-ocean ridge basalts (CRB_2); and c) a high Mg#, LREE-enriched tholeiitic basalt suite (CRB_3). Suites CRB_1 and CRB_2 are associated with spreading centres and high heat flow and are the most prospective hosts for VMS mineralization in the Campbell Range belt. This setting would provide not only a heat source for fluid circulation, but spreading would also provide faults and fracture conduits for upwelling and downwelling hydrothermal fluids.

Although there have been new insights into the geological evolution of YTT in the Finlayson Lake district over the past several years (e.g., Murphy, 1998; Hunt, 1998a, b; Murphy and Piercey, this volume), the results presented here, and by the above authors, have enlightened us to the complex geological, geochemical and tectonic relationships in this region. With continuing multidisciplinary field, geochemical, geochronological and isotopic studies we shall obtain a clearer picture of this enigmatic terrane of the Canadian Cordillera.

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REFERENCES

Barley, M.E. and Groves, D.I., 1992. Supercontinent cycles and the distribution of metal deposits through time. Geology, vol. 20, p. 291-294.

Barrie, C.T., Ludden, J.N and Green, T.H., 1993. Geochemistry of volcanic rocks associated with Cu-Zn and Ni-Cu deposits in the Abitibi Subprovince. Economic Geology, vol. 88, p. 1341-1358.

Bédard, J.H., Lauzière, K., Tremblay, A. and Sangster, A., 1998. Evidence for forearc seafloor-spreading from the Betts Cove ophiolite, Newfoundland: oceanic crust of boninitic affinity. Tectonophysics, vol. 284, p. 233-245.

Bloomer, S.H., Taylor, B., MacLeod, C., Stern, R.J., Fryer, P., Hawkins, J.W. and Johnson, L., 1995. Early arc volcanism and the ophiolite problem: a perspective from drilling in the western Pacific. *In:* Active Margins and Marginal Basins of the Western Pacific. B. Taylor and J. Natland (eds.), American Geophysical Union, Monograph 88, p. 1-30.

Campbell, I.H., Franklin, J.M., Gorton, M.P., Hart, T.R. and Scott., S.D., 1981. The role of subvolcanic sills in the generation of massive sulfide deposits. Economic Geology, vol. 76, p. 2248-2253.

Campbell, I.H., Coad, P., Franklin, J.M., Gorton, M.P., Scott, S.D., Sowa, J. and Thurston, P.C., 1982. Rare earth elements in volcanic rocks associated with Cu-Zn massive sulphide mineralization: A preliminary report. Canadian Journal of Earth Sciences, vol. 19, p. 619-623.

Coish, R.A., Hickey, R. and Frey, F., 1982. Rare earth element geochemistry of the Betts Cove ophiolite, Newfoundland: complexities in ophiolite formation. Geochemica et Cosmochimica Acta, vol. 46, p. 2117-2134.

Crawford, A.J., Falloon, T.J. and Green, D.H., 1989. Classification, petrogenesis and tectonic setting of boninites. *In:* Boninites, A.J. Crawford (ed.), Unwin Hyman, p. 1-49.

Dunning, G.R., Swinden, H.S., Kean, B.F., Evans, D.T.W. and Jenner, G.A., 1991. A Cambrian island arc in Iapetus: Geochronology and geochemistry of the Lake Ambrose volcanic belt, Newfoundland Appalachians. Geological Magazine, vol. 128, p. 1-17.

Faloon, T.J. and Crawford, A.J., 1991. The petrogenesis of high-calcium boninite lavas dredged from the northern Tonga ridge. Earth and Planetary Science Letters, vol. 192, p. 375-394.

Franklin, J.M., Lydon, J.W. and Sangster, D.F., 1981. Volcanic-associated massive sulphide deposits. Economic Geology 75th Anniversary Volume, p. 465-657.

Galley, A.G., 1995. Target vectoring using lithogeochemistry: Applications to the exploration for volcanic-hosted massive sulphide deposits. Canadian Institute of Mining and Metallurgy Bulletin, vol. 88, p. 15-27.

Galley, A.G., 1996. Geochemical characteristics of subvolcanic intrusions associated with Precambrian massive sulphide deposits. *In:* Trace Element Geochemistry of Volcanic Rocks: Applications for Massive Sulphide Exploration, D.A. Wyman (ed.), Geological Association of Canada, short course notes, vol. 12, p. 239-278.

Giaramita, M., MacPherson, G.J. and Phipps, S.P., 1998. Petrologically diverse basalts from a fossil oceanic forearc in California: The Llanada and Black Mountain remnants of the Coast Range ophiolite. Geological Society of America Bulletin, vol. 110, p. 553-571.

Grant, S.L., 1997. Geochemical, radiogenic tracer isotopic, and U-Pb geochronological studies of Yukon-Tanana Terrane rocks from the Money Klippe, southeastern Yukon, Canada. Unpublished M.Sc. thesis, University of Alberta, Edmonton, Alberta, 177 p.

Hickey, R.L. and Frey, F.A., 1982. Geochemical characteristics of boninite series volcanics: Implications for their source. Geochemica et Cosmochimica Acta, vol. 46, p. 2099-2115.

Hunt, J.A., 1997. Massive sulphide deposits in the Yukon-Tanana and adjacent terranes. *In:* Yukon Exploration and Geology 1996. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 35-45.

Hunt, J.A., 1998a. The setting of volcanogenic massive sulphide deposits in the Finlayson Lake district. *In:* Yukon Exploration and Geology 1997. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 99-104.

Hunt, J.A., 1998b. Recent discoveries of volcanic-associated massive sulphide deposits in the Yukon. Canadian Institute of Mining and Metallurgy, Bulletin, vol. 90, p. 56-65.

Hunt, J.A. and Murphy, D.C., 1998. A note on preliminary bedrock mapping in the Fire Lake area. *In:* Yukon Exploration and Geology 1997. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 59-68.

Jenner, G.A., 1981. Geochemistry of high-Mg andesites from Cape Vogel, Papua New Guinea. Chemical Geology, vol. 33, p. 307-322.

Johnson, L.E. and Fryer, P., 1990. The first evidence for MORB-like lavas from the outer Mariana forearc: Geochemistry, petrography and tectonic implications. Earth and Planetary Science Letters, vol. 100, p. 304-316.

Kerrich, R. and Wyman, D.A., 1996. Trace element systematics of igneous rocks in mineral exploration: An overview. *In:* Trace Element Geochemistry of Volcanic Rocks: Applications for Massive Sulphide Exploration, D.A. Wyman (ed.), Geological Association of Canada, short course notes vol. 12, p. 1-50.

Kerrich, R. and Wyman, D.A., 1997. Review of developments in trace-element fingerprinting of geodynamic settings and their implications for mineral exploration. Australian Journal of Earth Sciences, vol. 44, p. 465-487.

Kostopoulos, D.K. and Murton, B.J., 1992. Origin and distribution of components in boninite genesis: significance of the OIB component. *In:* Ophiolites and their Modern Oceanic Analogues, L.M. Parson, Murton, B.J. and Browning, P. (eds.), Geological Soceity Special Publication Number 60, p. 133-154.

Langmuir, C.H., Klein, E.M. and Plank, T., 1992. Petrological systematics of mid-ocean ridge basalts: Constraints on melt generation beneath ocean ridges. *In:* Mantle Flow and Melt Generation and Mid-Ocean Ridges. J. Phipps-Morgan, D.K. Blackman and J.M. Sinton (eds.), American Geophysical Union, Geophysical Monograph 71, p. 193-280.

Lentz, D.R., 1998. Petrogenetic evolution of felsic volcanic sequences associated with Phanerozoic volcanic-hosted massive sulphide systems: The role of extensional geodynamics. Ore Geology Reviews, vol. 12, p. 289-327.

Lesher, C.M., Goodwin, A.M., Campbell, I.H. and Gorton, M.P., 1986. Trace element geochemistry of ore-associated and barren felsic metavolcanic rocks in the Superior Province, Canada. Canadian Journal of Earth Sciences, vol. 23, p. 222-237.

McKenzie, D. and Bickle, M.J., 1988. The volume and composition of melt generated by extension of the lithosphere. Journal of Petrology, vol. 29, p. 625-679.

McKenzie, D. and O'Nions, R.K., 1991. Partial melt distributions from inversion of rare earth element concentrations. Journal of Petrology, vol. 32, p. 1021-1091.

Mortensen, J.K., 1992. Pre-mid-Mesozoic tectonic evolution of the Yukon-Tanana Terrane, Yukon and Alaska. Tectonics, vol. 11, p. 836-853.

Mortensen, J.K. and Jilson, G.A., 1985. Evolution of the Yukon-Tanana Terrane: Evidence from southeastern Yukon Territory. Geology, vol. 13, p. 806-810.

Murphy, D.C., 1997. Preliminary geological map of Grass Lakes, Pelly Mountains, southeastern Yukon (105G/7). Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, Open File 1997-3, 1:50 000 scale.

Murphy, D.C., 1998. Stratigraphic framework for syngenetic mineral occurrences, Yukon-Tanana Terrane south of Finlayson Lake: A progress report. *In:* Yukon Exploration and Geology 1997. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 51-58.

Murphy, D. and Piercey, S.J., 1999. Finlayson project: Geological evolution of Yukon-Tanana Terrane and its relationship to Campbell Range belt, northern Wolverine Lake map area, southeastern Yukon. *In:* Yukon Exploration and Geology 1998, C.F. Roots and D.S. Emond (eds.), Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 47-62.

Murphy, D.C. and Timmerman, J.T., 1997. Preliminary geology of the northeast third of the Grass Lakes area, Pelly Mountains, southeastern Yukon. *In:* Yukon Exploration and Geology 1996. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 29-32.

Nelson, J.L., 1993. The Sylvester allochthon: Upper Paleozoic marginal-basin and island-arc terranes in northern British Columbia. Canadian Journal of Earth Sciences, vol. 30, p. 631-643.

Pearce, J.A., Harris, N.B.W. and Tindle, A.G., 1984. Trace element discrimination diagrams for the tectonic interpretation of granitic rocks. Journal of Petrology, vol. 25, p. 956-983.

Pearce, J.A., van der Laan, S.R., Arculus, R.J., Murton, B.J., Ishii, T., Peate, D.W. and Parkinson, I.J., 1992. Boninite and Harzburgite from leg 125 (Bonin-Mariana Forearc): A case study of magma genesis during the initial stages of subduction. *In:* Proceedings of the Ocean Drilling Program, Scientific Results, Sites 778-786, Bonin/Mariana Region. P. Fryer, J.A. Pearce, L.B. Stokking et al. (eds.), p. 623-659.

Piercey, S.J., Jenner, G.A. and Wilton, D.H.C., 1997. The stratigraphy and geochemistry of the southern Pacquet Harbour Group, Baie Verte Peninsula, Newfoundland: Implications for mineral exploration. *In:* Current Research, Newfoundland Department of Mines and Energy, Geological Survey Branch, Report 97-1, p. 119-139.

Plint, H.E. and Gordon, T.M., 1997. The Slide Mountain Terrane and the structural evolution of the Finlayson Lake fault zone, southeastern Yukon. Canadian Journal of Earth Sciences, vol. 34, p. 105-126.

Rollinson, H.R., 1993. Using Geochemical Data: Evaluation, Presentation, Interpretation. Longman Group, UK Ltd., 352 p.

Sebert, C. and Hunt, J.A., 1999 (this volume). A note on preliminary lithogeochemistry of the Fire Lake area. *In:* Yukon Exploration and Geology 1998, C.F. Roots and D.S. Emond (eds.), Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 139-142.

Shervais, J.W., 1982. Ti-V plots and the petrogenesis of modern and ophiolitic lavas. Earth and Planetary Science Letters, vol. 59, p. 101-118.

Stern, R.J. and Bloomer, S.H., 1992. Subduction zone infancy: Examples from the Eocene Izu-Bonin-Mariana and Jurassic California Arcs. Geological Society of America Bulletin, vol. 104, p. 1621-1636.

Sun, S.S. and McDonough, W.F., 1989. Chemical and isotopic systematics of oceanic basalts: Implications for mantle composition and processes. *In:* Magmatism in the Ocean Basins, A.D. Saunders and M.J. Norry (eds.), Geological Society Special Publication 42, p. 313-345.

Swinden, H.S., 1991. Paleotectonic setting of volcanogenic massive sulphide deposits in the Dunnage Zone, Newfoundland Appalachians. Canadian Institute of Mining and Metallurgy Bulletin, vol. 84, p. 59-69.

Swinden, H.S., 1996. The application of volcanic geochemistry to the metallogeny of volcanic-hosted sulphide deposits in central Newfoundland. *In:* Trace Element Geochemistry of Volcanic Rocks: Applications for Massive Sulphide Exploration, D.A. Wyman (ed.), Geological Association of Canada, short course notes vol. 12, p. 329-358.

Taylor, S.R. and McLennan, S.M., 1985. The continental crust: its composition and evolution. Blackwell Scientific Publications, Oxford, 312 p.

Tempelman-Kluit, D.J., 1979. Transported cataclasite, ophiolite and granodiorite in Yukon: Evidence for arc-continent collision. Geological Survey of Canada, Paper 79-14, 27 p.

Umino, S. and Kushiro, I, 1989. Experimental Studies on boninite petrogenesis. *In:* Boninites. A.J. Crawford (ed.). Unwin-Hyman, p. 89-111.

Wheeler, J.O. and McFeely, P., 1991. Tectonic assemblage map of the Canadian Cordillera and adjacent parts of the United States of America. Geological Survey of Canada, Map 1712A, 1:2 000 000 scale.

Winchester, J.A. and Floyd, P.A., 1977. Geochemical discrimination of different magma series and their differentiation products using immobile elements. Chemical Geology, vol. 20, p. 325-343.

A note on preliminary lithogeochemistry of the Fire Lake area

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ABSTRACT

The Fyre Lake volcanic-hosted massive sulphide (VMS) deposit is located about 160 km northwest of Watson Lake in the Finlayson Lake district of southeastern Yukon. The deposit is hosted by Devonian (?) and Mississippian rocks of the Yukon-Tanana Terrane and occurs close to the contact between chlorite schist and overlying carbonaceous phyllite. Copper-cobalt-gold mineralization occurs in two parallel zones: West Kona and East Kona.

The chemical composition and rare earth element (REE) pattern of chlorite schist which hosts the Kona zones is unique in the Fire Lake area. The data indicate that the protolith of these meta-volcanic rocks has a boninitic affinity and was likely derived from a depleted source region. Mafic meta-volcanic rocks (chlorite schist) elsewhere in this area are tholeiitic and may have developed in an arc or rift-related setting. Analyses of psammitic schists in the hanging wall of the West Kona zone indicate the rocks are felsic in composition and were likely deposited in a mature arc or continental-margin setting.

RÉSUMÉ

Le gisement Fyre Lake de sulfures massifs d'origine volcanique (SMV) est situé à environ 160 km au nord-ouest de Watson Lake dans le district de Finlayson Lake au sud-est du Yukon. Le gisement se trouve dans les roches dévoniennes (?) et mississippiennes du terrane de Yukon-Tanana à proximité du contact entre le chloritoschiste et la phyllite carbonée sus-jacente. Deux zones parallèles sont minéralisées en cuivre, en cobalt et en or : les zones West Kona et East Kona.

La composition chimique et le profil en éléments du groupe des terres rares du chloritoschiste renfermant les zones Kona sont particuliers dans la région du lac Fyre. Les données indiquent que le protolithe de ces roches métavolcaniques présente une affinité boninitique et provenait vraisemblablement d'une région source appauvrie. Les roches métavolcaniques (chloritoschiste) ailleurs dans cette région sont tholéiitiques et se sont vraisemblablement formées dans un cadre de guirlande continentale ou de guirlande océanique. Des analyses des micaschistes arénacés dans la lèvre supérieure de la zone West Kona indiquent que les roches sont de composition felsique et ont vraisemblablement été déposées dans un cadre continental à maturité avec un apport mineur d'une source davantage primitive.

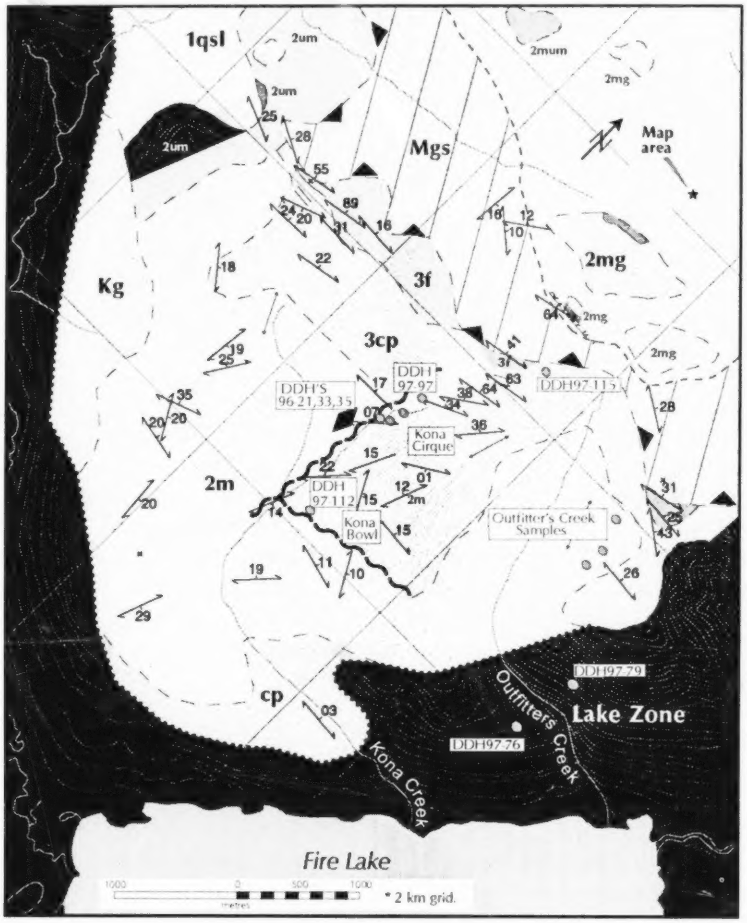


Figure 1. Location of the Fire Lake area plus the Kona Cirque, Outfitter's Creek, Lake Zone and Kona Bowl areas. Black diamond is the Fyre Lake deposit, and black triangles on over-riding plate of a thrust fault. Black area is vegetated and unmapped.

Kg *- Cretaceous age, weakly foliated, generally equigranular, medium- to coarse-grained biotite-muscovite granite*

Mgs *- Mississippian medium- to coarse-grained, variably strained granite.*

2mg *- fine- to coarse-grained gabbro*

3f *- light grey, tan to white platy quartz-muscovite schist, locally with mm-scale quartz and feldspar augen (at least in part felsic metavolcanic rocks)*

3cp *- medium to dark grey carbonaceous muscovite-quartz schist or phyllite, quartzite, uncommon light grey marble*

cp *- lithologically similar to 3cp, but stratigraphic position is unclear (may underlie unit 2)*

2m *- massive calcareous actinolite-plagioclase- chlorite-biotite schist, subtly layered plagioclase-actinolite-chlorite schist, and lesser carbonaceous phyllite and quartzite.*

1qsl *- lower quartzose metaclastic unit: biotite-quartz- muscovite schist and lesser biotite-muscovite quartz schist and plagioclase-quartz-chlorite-biotite schist*

INTRODUCTION

The Fyre Lake deposit (Foreman, 1998; Blanchflower et al., 1997; Yukon Minfile 105G 034; 61°13'35"N, 130°30'49"W) is located on the east side of Fire Lake about 160 km northwest of the town of Watson Lake in the Finlayson Lake VMS district of southeastern Yukon (Fig. 1). Copper-cobalt-gold mineralization is hosted by Devono(?)-Mississippian rocks of the Yukon-Tanana Terrane. This mineralization is known as the Kona Zone and occurs close to the contact between chlorite schist and overlying carbonaceous phyllite (Blanchflower et al., 1997; Hunt and Murphy, 1998).

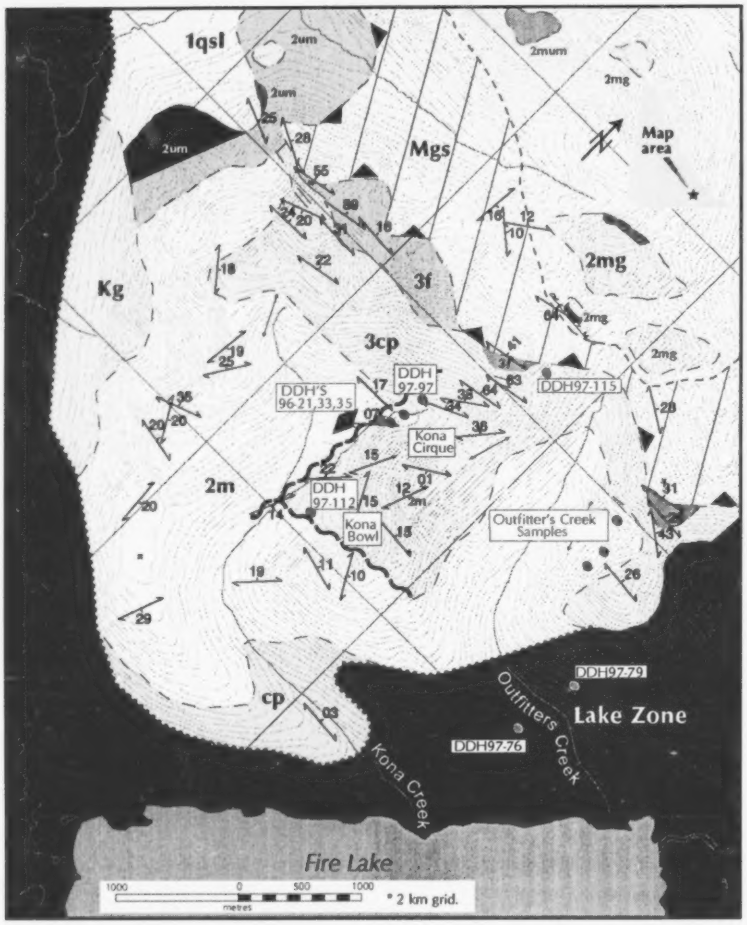
During fieldwork in 1996 and 1997, samples were collected for a lithogeochemical study of the Fyre Lake deposit in an attempt to define the signature of ore-bearing strata. Samples were collected from the Kona Cirque, Kona Bowl, Lake Zone and Outfitter's Creek areas (Fig. 1). Preliminary results from these analyses are presented in this paper; more detailed results will be presented in Sebert et al. (in prep.). These results complement an ongoing lithogeochemical study of the Finlayson Lake area by Piercey et al. (this volume).

GEOCHEMISTRY

CHLORITE SCHIST

In general, chlorite schist from the Fire Lake area has a silica content similar to basaltic and andesitic rocks (Fig. 2a), and Zr/TiO_2 ratios typical of subalkalic rocks (Fig. 2b).

Kona Cirque chlorite schist which hosts the Kona deposit contains between 53 and 58% SiO_2 and is highly mafic. It can easily be distinguished from chlorite schist in the Lake Zone, Outfitter's Creek and Kona Bowl areas (Fig. 1) on the basis of major and trace element chemistry. The Kona Cirque chlorite schist has higher MgO, SiO_2 and Cr, and lower TiO_2 and Zr contents. Chondrite-normalized REE patterns for the Kona Cirque chlorite schists have a distinctive spoon-shaped pattern. The major and trace elements chemistry suggests that these rocks are of boninitic affinity. The Rare Earth Element (REE) patterns of the Kona Cirque chlorite schist are similar to Type C boninites from the Upper



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Pillow lavas of the Troodos Ophiolite (Fig. 3; Cameron, 1985).

Lake Zone chlorite schist displays whole rock chemistry typical of basaltic volcanic rocks (Fig. 2a and b). Samples from the Outfitter's Creek area range from basaltic to andesitic in composition and that from the Kona Bowl is andesitic. Nb and Ta are depleted relative to Light Rare Earth Elements (LREE) and Large Ion Lithophile Elements (LILE) in the rocks from the Lake Zone and Outfitter's Creek area, which is suggestive of eruption in an arc setting. The REE profiles of chlorite schist samples from the Lake Zone, Outfitter's Creek area and Kona Bowl are similar to those of arc-related tholeiitic rocks and to tholeiites erupted in response to rifting of marginal basins (Fig. 4).

PSAMMITIC SCHIST AND FELSIC META-VOLCANIC ROCKS

Samples of quartz-biotite schist from the hanging wall of the West Kona zone are felsic in composition and display a similar chondrite normalized REE pattern to the North American Shale Curve and average upper crust (Fig. 5). One sample of potassium feldspar phyric metavolcanic rock, collected on the east side of Kona Cirque, is rhyolitic in composition and has a similar REE profile to the psammitic schists.

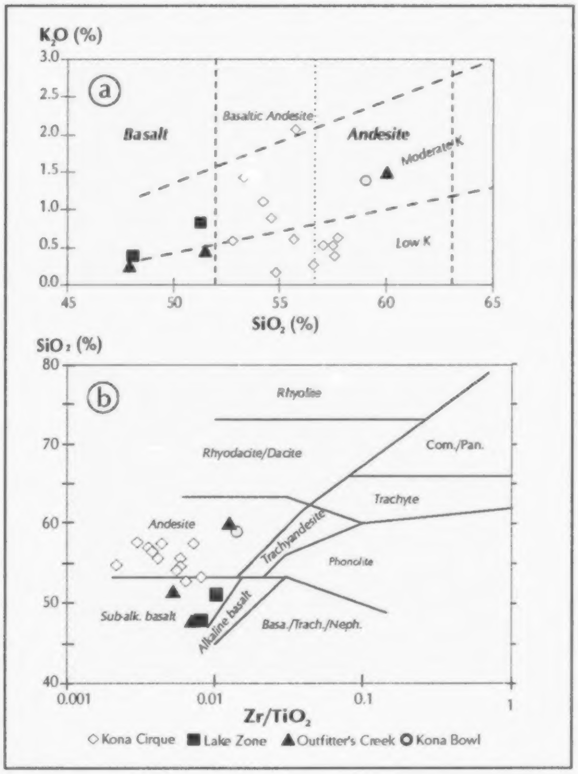

Figure 2. *a: K_2O versus SiO_2 plot (Peccerillo and Taylor, 1976), b: SiO_2 versus Zr/TiO_2 diagram (Winchester and Floyd, 1977).*

CONCLUSIONS

The application of lithogeochemistry at the Fyre Lake property has yielded significant results with regards to mineral exploration and the understanding of the tectonic origin of the host Yukon-Tanana Terrane rocks.

On the property there are distinct chemical differences between chlorite schist which hosts the copper-cobalt-gold Kona zone mineralization and those in other areas which are barren. Lithogeochemical sampling and analysis can thus be used as a tool to aid in separating schist units which are not readily distinguishable in outcrop or drill core.

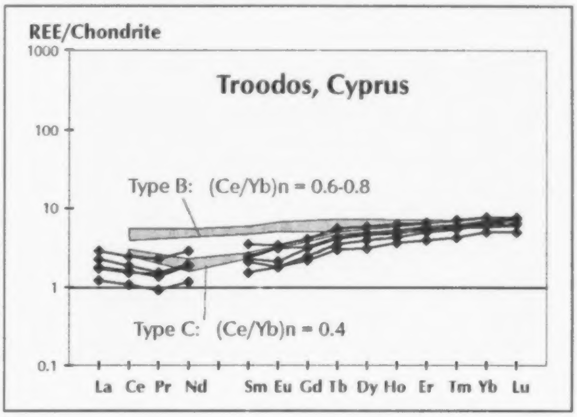

Figure 3. *Comparison of REE patterns of the Kona Cirque mafic schists to boninitic rocks from Troodos Ophiolite, Cyprus (Cameron, 1985). Chondrite composition is from Evensen et al. (1978).*

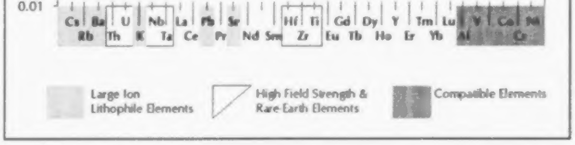

Figure 4. *Comparison of chlorite schist samples from the Lake zone to average Sunda Arc tholeiite (Whitford et al., 1979) and rift-related tholeiitic rocks from the Massett Formation, Queen Charlotte Islands (Hamilton and Dostal, 1993). N-MORB composition from Hofmann (1988).*

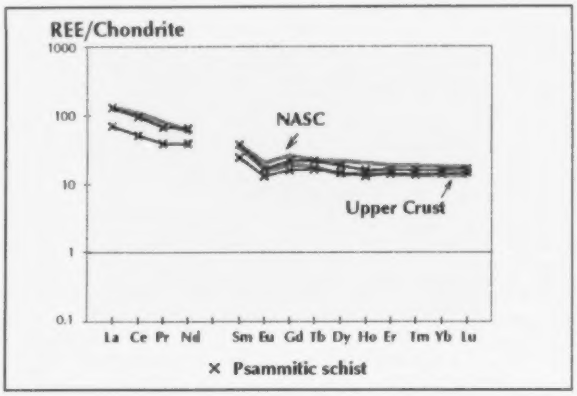

Figure 5. *Chondrite-normalized REE plots for psammite samples. The North American Shale Curve (Grommet et al., 1984) and Upper Crust (Taylor and McLennan, 1985) are shown for reference (thick grey). Chondrite composition is from Evensen et al. (1978).*

Major and trace element chemistry suggests that the Kona Cirque chlorite schists have a boninitic affinity, while samples from the Lake Zone, Outfitter's Creek and Kona Bowl areas are similar to arc-related tholeiitic rocks.

Psammites in the hanging wall of the West Kona zone have major and trace element chemistry that suggests they were originally sediments deposited in an advanced tectonic setting such as a continental margin or arc.

Overall, it is suggested that rocks in the Fire Lake area were deposited in an arc-related environment influenced by subduction processes.

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REFERENCES

Blanchflower, D., Deighton, J. and Foreman, I., 1997. The Fyre Lake deposit: A new copper-cobalt-gold VMS discovery. *In:* Yukon Exploration and Geology 1996, Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 46-52.

Cameron, W.E., 1985. Petrology and origin of the primitive lavas from the Troodos ophiolite, Cyprus. Contributions to Mineralogy and Petrology, vol. 89, p. 239-255.

Evensen, N.M., Hamilton, P.J. and O'Nions, R.K., 1978. Rare earth abundances in chondritic meteorites. Geochimica Cosmochimica Acta, vol. 42, p. 1199-1212.

Foreman, I., 1997. The Fyre Lake project 1998: Geology and mineralization of the Kona massive sulphide deposit. *In:* Yukon Exploration and Geology 1997. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 105-113.

Gromet, L.P., Dymek, R.F., Haskin, L.A. and Korotev, R.L., 1984. The "North American shale composite": Its composition, major and trace element characteristics. Geochimica Cosmochimica Acta, vol. 48, p. 2469-2482.

Hamilton, T.S. and Dostal, J., 1993. Geology, geochemistry and petrogenesis of Middle-Tertiary volcanic rocks of the Queen Charlotte Islands, British Columbia, Canada. Journal of Volcanology and Geothermal Research, vol. 59, p. 77-99.

Hofmann, A.W., 1988. Chemical differentiation of the earth: The relationship between mantle, continental crust, and oceanic crust. Earth and Planetary Science Letters, vol. 90, p. 297-314.

Hunt. J.A. and Murphy, D.C., 1998. A note on preliminary bedrock mapping in the Fire Lake area. *In:* Yukon Exploration and Geology 1997. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 59-68.

Peccerillo, R. and Taylor, S.R., 1976. Geochemistry of Eocene calc-alkaline volcanic rocks from the Kastamonu area, northern Turkey. Contributions to Mineralogy and Petrology, vol. 58, p. 63-81.

Piercey, S.J., Hunt, J.A. and Murphy, D.C., 1999 (this volume). Lithogeochemistry of meta-volcanic rocks from Yukon-Tanana Terrane, Finlayson Lake region, Yukon: Preliminary results. *In:* Yukon Exploration and Geology 1998, C.F. Roots and D.S. Emond (eds.), Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 125-138.

Sebert, C., Hunt, J.A., Foreman, I., Roberts, W. and Barrett, T. (in prep). Geology, structure and lithogeochemistry of the Fyre Lake deposit.

Taylor, S.R. and McLennan, S.M., 1985. The continental crust: Its composition and evolution. Blackwell, Oxford, 312 p.

Whitford, D.J., Nicholls, I.A. and Taylor, S.R., 1979. Spatial variations in the geochemistry of Quaternary lavas across the Sunda Arc and Bali. Contributions to Mineralogy and Petrology, vol. 70, p. 341-356.

Winchester, J.A. and Floyd, P.A., 1977. Geochemical discrimination of different magma series and their differentiation products using immobile elements. Chemical Geology, vol. 20, p. 325-343.

Yukon Minfile. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada. Also available from Hyperborean Productions, Whitehorse, Yukon.

The exotic nature of the Last Peak eclogite in the Teslin zone, south-central Yukon Territory

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de Keijzer, M. and Williams, P.F., 1999. The exotic nature of the Last Peak eclogite in the Teslin zone, south-central Yukon Territory. *In:* Yukon Exploration and Geology 1998. C.F. Roots and D.S. Emond (eds.), Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 143-154.

ABSTRACT

The history of an eclogite sample and a mica schist sample from the western Teslin zone are discussed in view of garnet zoning profiles. The preliminary metamorphic results support the contention (de Keijzer et al., in press), based on earlier regional and structural arguments, of a structural contact (the "basal thrust" of de Keijzer et al., in press) between the Last Peak eclogite (part of the Anvil assemblage) and metasedimentary rocks of North American affinity to the west of it. Consequently, the eclogite is considered "exotic" with respect to the metasedimentary rocks. The proposed position of the Last Peak eclogite, a few hundred metres above the interpreted basal thrust within the zone of ductile thrusting, explains why it has experienced pervasive amphibolitization (hydration) since fault zones commonly act as conduits for fluid. It is unclear how much of the amphibolite-to-greenschist facies Anvil rocks surrounding the eclogite have experienced earlier high-pressure metamorphism.

RÉSUMÉ

Les histoires métamorphiques d'un échantillon d'éclogite (éclogite de Last Peak) et d'un échantillon de micaschiste de la partie ouest de la zone de Teslin sont discutées à la lumière des profils de zonation des grenats. Les résultats préliminaires appuient la thèse, basée sur des arguments régionaux et structuraux antérieurs, d'une «chevauchement de base» entre l'éclogite de Last Peak et les roches métasédimentaires présentes à l'ouest de celle-ci. En conséquence, l'éclogite est considérée «allochtone» par rapport à ces roches. Il est proposé que l'éclogite de Last Peak se situe au sein des roches de l'assemblage d'Anvil dans le compartiment supérieur près du chevauchement ductile qui sépare ces roches des roches nord-américaines du compartiment inférieur. La position de l'éclogite de Last Peak dans la zone de chevauchement ductile explique pourquoi elles ont subi une profonde amphibolitisation (hydratation) syncinétique puisque les zones faillées servent couramment de conduits pour les fluides.

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INTRODUCTION

Eclogite in the Omineca Belt in the Yukon is restricted to a few isolated occurrences and its structural setting is suspect (e.g., Foster et al., 1994; Erdmer et al., 1998). In this paper we present garnet zoning data from one of the eclogite occurrences, the Last Peak eclogite (cf. Erdmer and Helmstaedt, 1983), and from a mica schist, both from the western Teslin zone in south-central Yukon (Fig. 1). The zoning results provide important constraints on the metamorphic history of the eclogite and its surrounding rocks, and on the structural setting of the eclogite in the Teslin zone.

The Teslin zone was previously called the "Teslin suture zone" (cf. Tempelman-Kluit, 1979) or the "Teslin tectonic zone" (cf. Stevens, 1994). It includes the narrowest portion of the pericratonic Yukon-Tanana Terrane (Wheeler et al., 1991), and is bounded in the Last Peak area (NTS sheet 105E/9), by north-trending post-accretionary faults (Fig. 1), the d'Abbadie fault to the east and the Big Salmon fault to the west. Most of the Teslin zone rocks are assigned either to the Anvil or Yukon-Tanana Nisutlin assemblages (Figs. 1 and 2). Detailed descriptions of the Nisutlin and Anvil assemblages (principally comprising siliceous metasedimentary rocks and marble, and intermediate to ultramafic metavolcanic and metaplutonic rocks, respectively) are provided elsewhere (e.g., Tempelman-Kluit, 1979; Mortensen, 1992; Stevens, 1994; Stevens et al., 1996).

PREVIOUS WORK

The Teslin zone has been described as the fundamental boundary between the ancient continental margin of North America (referred to as North America) to the east and

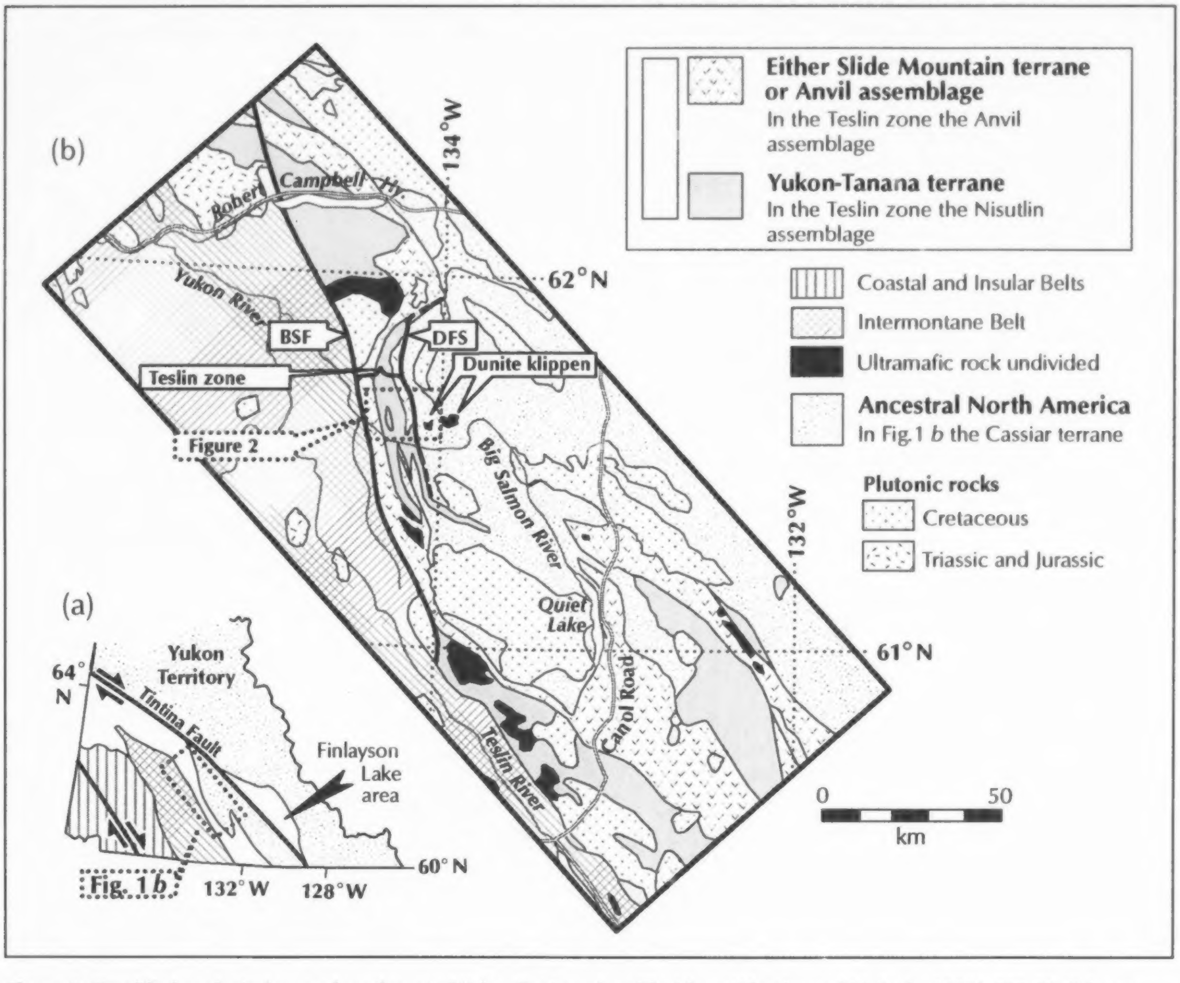
(b)
134°W
Robert Campbell Hy.
Yukon River
62°N
BSF
DFS
Dunite klippen
Teslin zone
Figure 2
Big Salmon River
132°W
Quiet Lake
Canol Road
Teslin River
61°N
(a)
Yukon Territory
64° N
Tintina Fault
Finlayson Lake area
60° N
Fig. 1b
132° W
128° W
Either Slide Mountain terrane or Anvil assemblage
In the Teslin zone the Anvil assemblage
Yukon-Tanana terrane
In the Teslin zone the Nisutlin assemblage
Coastal and Insular Belts
Intermontane Belt
Ultramafic rock undivided
Ancestral North America
In Fig.1 b the Cassiar terrane
Plutonic rocks
Cretaceous
Triassic and Jurassic
0
50
km

Figure 1. Simplified geological map of south-central Yukon Territory (modified from Wheeler and McFeely, 1991). BSF, Big Salmon fault; DFS, d'Abbadie fault system.

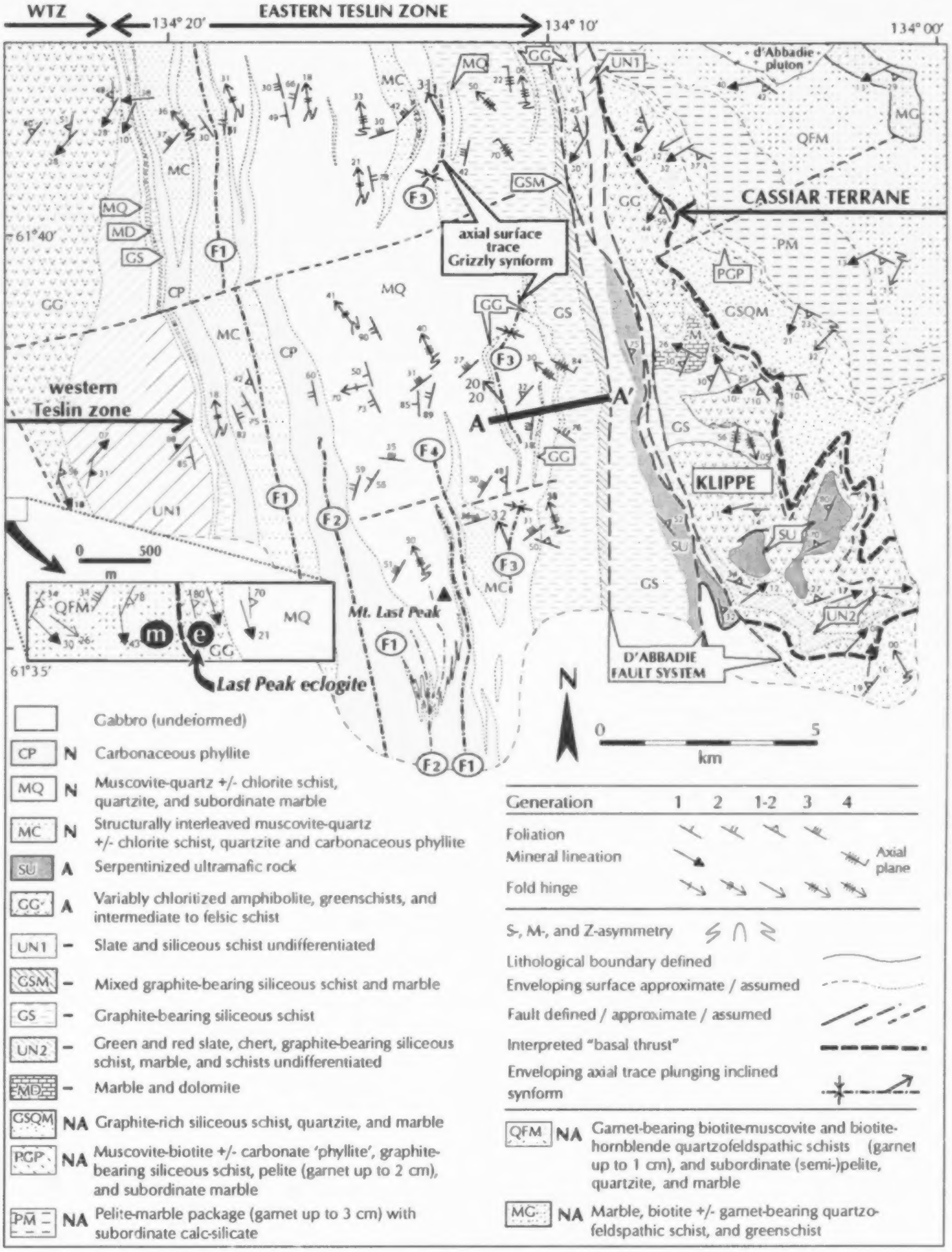
WTZ
EASTERN TESLIN ZONE
134° 20'
134° 10'
134° 00'
61°40'
61°35'
western Teslin zone
CASSIAR TERRANE
KLIPPE
d'Abbadie pluton
axial surface trace Grizzly synform
D'ABBADIE FAULT SYSTEM
Mt. Last Peak
Last Peak eclogite
A
A'
F1
F2
F3
F4
m
e
0
500
m
N
0
5
km
Gabbro (undeformed)
CP N Carbonaceous phyllite
MQ N Muscovite-quartz +/- chlorite schist, quartzite, and subordinate marble
MC N Structurally interleaved muscovite-quartz +/- chlorite schist, quartzite and carbonaceous phyllite
SU A Serpentinized ultramafic rock
GG A Variably chloritized amphibolite, greenschists, and intermediate to felsic schist
UN1 – Slate and siliceous schist undifferentiated
GSM – Mixed graphite-bearing siliceous schist and marble
GS – Graphite-bearing siliceous schist
UN2 – Green and red slate, chert, graphite-bearing siliceous schist, marble, and schists undifferentiated
MD – Marble and dolomite
GSQM NA Graphite-rich siliceous schist, quartzite, and marble
PGP NA Muscovite-biotite +/- carbonate 'phyllite', graphite-bearing siliceous schist, pelite (garnet up to 2 cm), and subordinate marble
PM NA Pelite-marble package (garnet up to 3 cm) with subordinate calc-silicate
Generation 1 2 1-2 3 4
Foliation
Mineral lineation
Axial plane
Fold hinge
S-, M-, and Z-asymmetry
Lithological boundary defined
Enveloping surface approximate / assumed
Fault defined / approximate / assumed
Interpreted "basal thrust"
Enveloping axial trace plunging inclined synform
QFM NA Garnet-bearing biotite-muscovite and biotite-hornblende quartzofeldspathic schists (garnet up to 1 cm), and subordinate (semi-)pelite, quartzite, and marble
MG NA Marble, biotite +/- garnet-bearing quartzofeldspathic schist, and greenschist

Figure 2. Geological map modified from de Keijzer et al. (in press) showing the subdivision and distribution of Nisutlin (N), Anvil (A), and North American (NA) rocks in the Last Peak area (NTS sheet 105E/9) (– in the legend implies undetermined affiliation). Shown in the inset map are the location of the two samples (black circles) used for garnet analyses (e = Last Peak eclogite sample; m = mica schist sample). A-A' corresponds to the vertical section shown in Figure 4.

allochthonous terranes of the Intermontane Belt (Wheeler et al., 1991) to the west (e.g., Hansen, 1989, 1990). Previous workers described the zone as discrete, with a steep foliation in contrast to more shallowly dipping foliations in adjacent areas (Fig. 3). The steep foliation, together with a single occurrence of eclogite on the eastern side of the zone, was considered evidence for the zone being a subduction-related lithospheric suture (Tempelman-Kluit, 1979; Erdmer and Helmstaedt, 1983; Erdmer, 1985, 1992; Hansen, 1988, 1989, 1990, 1992; Hansen and Dusel-Bacon, 1998; Hansen et al., 1991, Fig. 3a, b). The same evidence has been used in support of it being a crustal-scale transpression zone (Stevens, 1994, Fig. 3c), and this model was modified by Stevens and Erdmer (1996) to include a low-angle detachment separating Teslin zone rocks from underlying North American rocks (Fig. 3d). According to the suture models, the Teslin zone is the root zone of related rocks lying as klippen on North America to the east, and this belief is firmly entrenched in the literature (e.g., Tempelman-Kluit, 1979; Gordey, 1981; Erdmer, 1985, 1992; Hansen, 1989; Stevens, 1994).

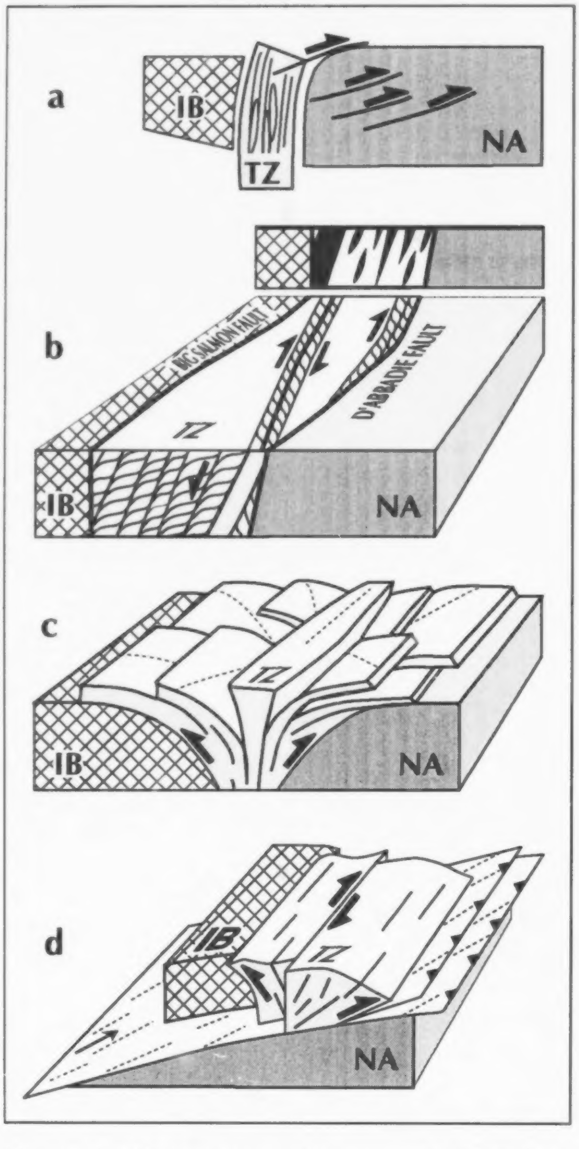

*Figure 3. Simplified crustal geometries proposed for the Teslin zone by **a)** Tempelman-Kluit (1979), **b)** Hansen (1989), **c)** Stevens (1994), **d)** Stevens and Erdmer (1996).*

The field relationships between the Last Peak eclogite and adjacent rocks/rock units are unclear because of (i) relatively poor exposure in the western Teslin zone, and (ii) intense ductile deformation which has affected all rock units and their contacts and obliterated the original nature of these contacts (e.g., Tempelman-Kluit, 1979; Erdmer and Helmstaedt, 1983; Erdmer, 1985; Hansen, 1989). Consequently, the regional structural context of the Last Peak eclogite is ambiguous. The structural framework of the Teslin zone proposed by de Keijzer et al. (in press), briefly described below, is substantially different, at all scales, to earlier interpretations. Although the origin of the eclogite is still ambiguous, the conclusions of de Keijzer et al. (in press) provide the basis for the first coherent interpretation of its structural setting.

SALIENT CONCLUSIONS OF DE KEIJZER ET AL. (in press)

Mapping at scales 1:5 000 to 15 000 revealed that primary layering of Anvil, Nisutlin, and North American rocks, in both the Teslin zone and east of it, has been transposed (see Williams, 1983 and references therein) by two generations of folding (F_1 and F_2). The transposed layering, together with S_1-S_2 axial plane cleavages, defines the transposition foliation S_T. The F_1 and F_2 folds occur at up to km-scale as can be seen, for example, south of Mt. Last Peak (Fig. 2). Figure 4a shows a block diagram of part of the enveloping surface between carbonaceous phyllite (unit CP) and muscovite-quartz schist (unit MQ) in the eastern Teslin zone. The map-scale continuity of this contact contrasts with the structure proposed by previous workers (e.g., Tempelman-Kluit, 1979; Erdmer, 1985) in which the Teslin zone was characterized by the discontinuous nature of lithologic units, and interpreted as representing a mélange. Despite transposition, map-scale continuity has also been observed in other parts of the Teslin zone (Stevens, 1994; Stevens et al., 1996) and in the Cassiar Terrane (the North American rocks east of the d'Abbadie fault system; see Figs. 1 and 2).

The F_1-F_2 folds are refolded by the regional-scale shallowly northwest-plunging F_3 Grizzly synform (Figs. 4b and 5; de Keijzer and Williams, 1997; de Keijzer et al., in press). The generally steep orientation of S_T in the Teslin zone, in contrast to S_T in adjacent rocks to the east, coincides with the steep limb of the Grizzly synform (Fig. 5c) which has a minimum structural thickness of 9 km. This fold has a shallow limb in the easternmost part of the zone (Figs. 4b and 5c) and immediately east of the zone which is cut by the d'Abbadie fault system. Thus, the steep attitude of fabrics in the Teslin zone is not evidence for a steep crustal-scale shear zone, whether it be suture-related or not. If a suture exists between the obducted Anvil and Yukon-Tanana Nisutlin assemblages and ancient North America, it is a shear zone at the base of the obducted rocks which has been folded by the Grizzly synform. However, there is no reason to interpret this obduction boundary as a suture since evidence of high pressure metamorphism during easterly thrusting is lacking (see also below); S_T development, and accommodation of shear by S_T, resulted in amphibolitization of the Last Peak eclogite.

In the suture interpretation, North American rocks are restricted to the east side of the zone, since the zone separates North America from truly allochthonous rocks to the west (Fig. 3). A consequence of the Grizzly synform is that North American rocks pass under the eastern Teslin zone and outcrop west of the Yukon-Tanana Nisutlin assemblage (Fig. 5). Thus, the western limit of North American basement in southern Yukon Territory could well be situated to the west of the Omineca Belt (if not removed by Cretaceous and younger transcurrent faulting; Gabrielse, 1985).

The results of de Keijzer et al. (in press) necessitate a reappraisal of earlier interpretations. The one example described here concerns the distribution of metamorphic grade. The recognition of an inverted metamorphic gradient in the Teslin zone (Tempelman-Kluit, 1979; Hansen, 1988, 1992), with amphibolite facies rocks and rare eclogite in the west, and greenschist facies rocks in the east, was used by proponents of the suture-interpretation to propose a westerly dip of the inferred subduction complex (i.e., Teslin zone). This argument is based on the hypothesis that the direction of increasing metamorphic grade records the polarity of the subduction zone (cf. Ernst, 1971). However, the inverted metamorphic gradient has been established on the overturned limb of the (previously unrecognized) F_3 Grizzly synform which formed post-peak metamorphism (de Keijzer, 1998, unpublished data) and has folded metamorphic isograds. Unfolding of the Grizzly synform positions the higher grade rocks at lower structural levels. Hence, there is no evidence for an inverted metamorphic gradient during the peak of regional metamorphism and no metamorphic argument therefore for the subduction model.

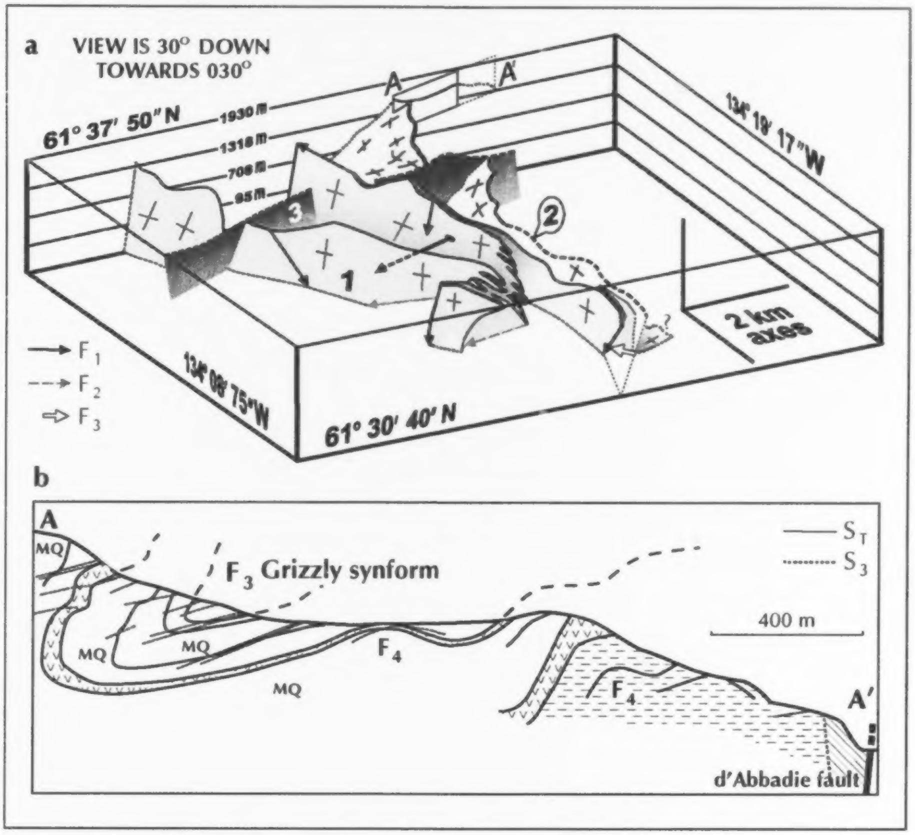

Figure 4. ***a)*** *Block diagram in orthographic projection showing (1) part of the contact between carbonaceous phyllite and muscovite-quartz schist in the eastern Teslin zone (top follows topography), (2) the axial plane of the F_3 Grizzly synform, (3) probable brittle normal faults (south-side-down; see de Keijzer et al., in press).* ***b)*** *Simplified vertical section showing the hinge of the Grizzly synform. See Figures 2 and 4a for location. Same legend as Figure 2.*

METAMORPHISM OF THE LAST PEAK ECLOGITE AND SURROUNDING ROCKS

Despite the lack of mineralogical evidence, Hansen (1992) claimed that the rocks in the western Teslin zone experienced "widespread high-pressure metamorphic conditions" (575–750°C and 0.9–1.7 GPa) overlapping with the estimated peak metamorphic conditions of the Last Peak eclogite (Erdmer and Helmstaedt, 1983). However, the vast majority of Teslin zone rocks record metamorphism under greenschist to amphibolite facies conditions (e.g., Tempelman-Kluit, 1979; Stevens, 1994; Hansen, 1989, 1992). Based on structural arguments, some workers (e.g., Tempelman-Kluit, 1979; Erdmer, 1985; Hansen, 1989) proposed an *in-situ* setting for the Last Peak eclogite, whereas others (e.g., Erdmer and Helmstaedt, 1983; de Keijzer and Williams, 1997; de Keijzer et al., in press) argued that the Last Peak eclogite is probably exotic (i.e., tectonically incorporated) with respect to the other Teslin zone rocks. The polyphase metamorphic history of the Last Peak eclogite, recording a profound, younger amphibolite to greenschist facies metamorphic overprint, has been previously documented by Erdmer and Helmstaedt (1983), Erdmer et al. (1998), and by de Keijzer et al. (in press). Besides unambiguous textural disequilibrium, chemical disequilibrium between biotite and amphibole and eclogitic garnet is indicated by garnet-biotite and garnet-hornblende thermometry which yielded geologically unreasonable high temperatures (in excess of 800°C; Erdmer et al., 1998).

In the following section, garnet zoning profiles from a partially amphibolitized eclogite sample (MK-97-3.6.1) and a mica schist sample (MK-97-2.2) from the western Teslin zone are compared. No significant variation in the orientation of S_T and the mineral lineation (L_M) was observed between the two sample locations. Analyses were performed on the JEOL 733 Superprobe at the University of New Brunswick, at an accelerating voltage of 15 kV, a current of 10 nA, a counting time of 40 seconds, and a beam diameter of 1–2 μm. The analyses were corrected using the ZAF method.

SAMPLE DESCRIPTION

The eclogite was collected at 530900E - 6830850N (elevation 760 m/2,500 ft) in unit GG of the Anvil assemblage, approximately 250 m east of the (transposed) contact with quartzofeldspathic and pelitic schists of unit QFM (see inset map Fig. 2). The physiography of this area and petrology of the eclogite were described in detail by Erdmer and Helmstaedt (1983) and Erdmer et al. (1998). Only a brief description of the eclogite sample is presented here. Garnet (Fig. 6a) comprises ~ 40% of the rock and is evenly distributed as small (mostly

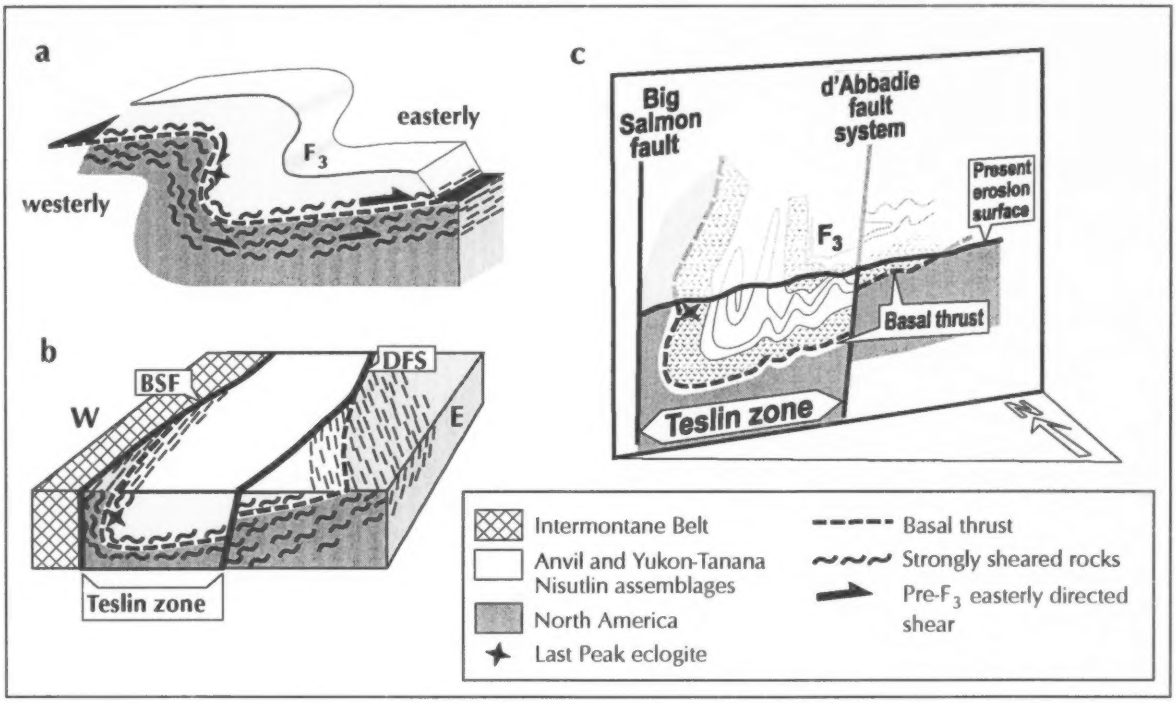
a
easterly
F3
westerly
b
BSF
DFS
W
E
Teslin zone
c
Big Salmon fault
d'Abbadie fault system
Present erosion surface
F3
Basal thrust
Teslin zone
N
▨ Intermontane Belt
☐ Anvil and Yukon-Tanana Nisutlin assemblages
▩ North America
✦ Last Peak eclogite
- - - - Basal thrust
~~~ Strongly sheared rocks
Pre-F3 easterly directed shear

Figure 5. Illustrations of the crustal geometry proposed by, and modified from, de Keijzer et al. (in press).
~~~

< 1 mm in diameter) sub-idioblastic grains with few inclusions of omphacite, rutile, quartz, epidote/zoisite(?), and albite. The remainder of the rock is comprised of Ca-amphibole (magnesiohornblende; locally forming intergrowths with (clino)zoisite), abundant rutile+/-ilmenite pairs rimmed by sphene, and minor oligoclase, biotite, and a second Ca-amphibole (magnesiohastingsite; rimming garnet, biotite, and the other amphibole). The sample lacks a noticeable foliation. In the rocks directly surrounding the eclogite, clinozoisite, sphene, Ca-amphiboles (magnesiohornblende-tschermakite) and oligoclase grew synkinematically at the expense of garnet and rutile (de Keijzer et al., in press). The (partial) breakdown of garnet and rutile is most profound in the more strongly foliated rocks.

The mica schist (Fig. 6b) was collected at 530550 E - 6830925 N (elevation 750 m/2,460 ft) in unit QFM, structurally a few

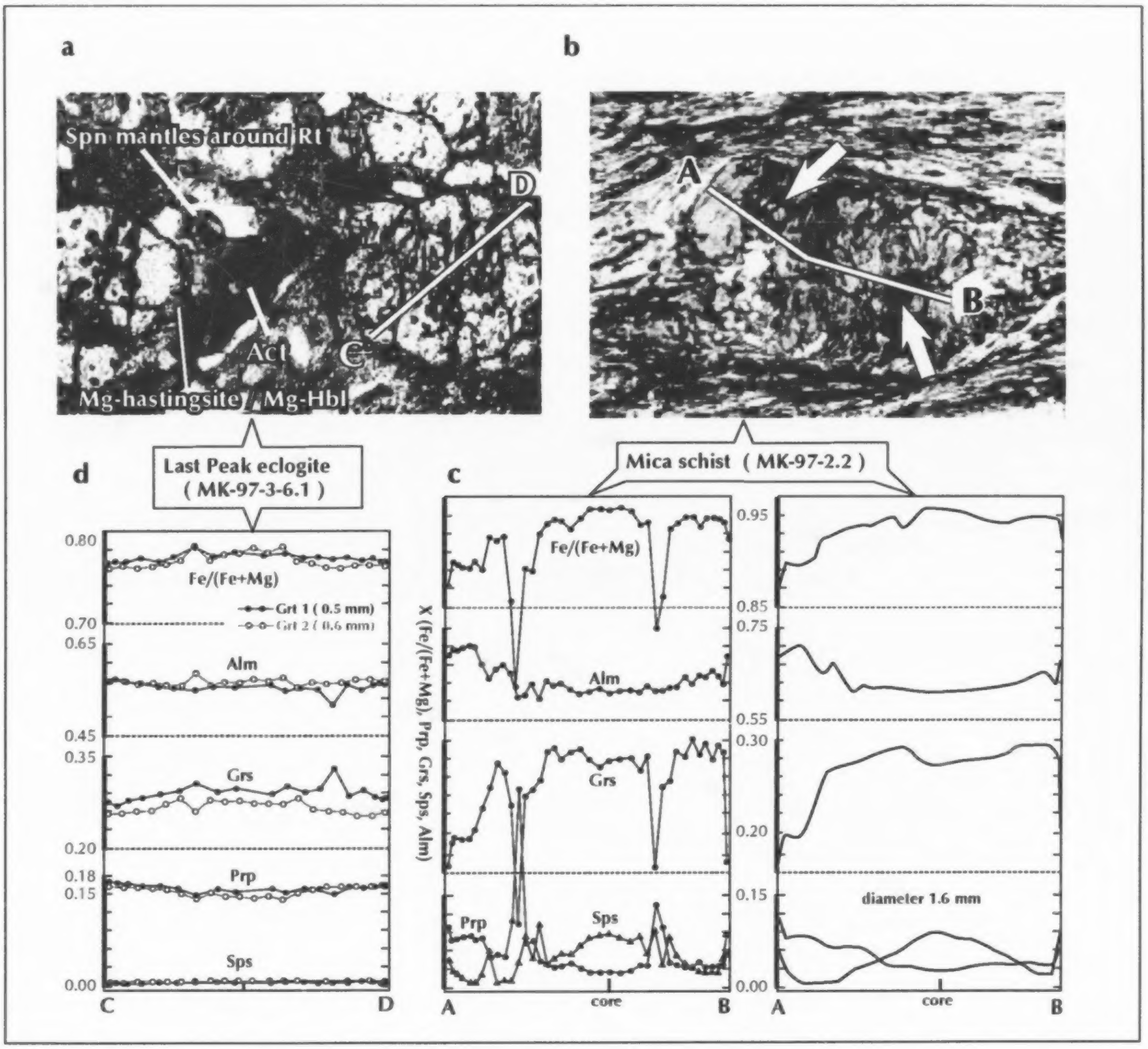

*Figure 6. **a)** Photomicrograph showing one of the eclogitic garnets used for chemical analysis. Note the absence of a foliation in this sample. **b)** Photomicrograph of the garnet grain used for chemical analysis in the mica schist sample. Note the profound resorbed nature of garnet. **c)** Zoning profile of the line A-B in (b). The two pronounced spikes correlate with regions of severe garnet resorption (areas pointed out by the white arrows in b); these have been filtered out in the right-hand portion of the figure. **d)** Zoning profile of the line C-D in (a).*

hundred metres west of the transposed contact with unit GG. S_T is defined by a preferred orientation of statically recrystallized biotite and white mica grains, a quartz and plagioclase shape fabric, strings of fine graphite, and the alignment of rare elongate rutile grains (some of which are rimmed by clinozoisite). S_T invariably bends around strongly resorbed garnet grains ≤ 2 mm in diameter. Some garnet grains show a sigmoidal inclusion pattern defined by quartz grains. Garnet breakdown resulted in the formation of random aggregates of secondary oligoclase–andesine, biotite, white mica, and quartz.

GARNET ZONING DATA

Representative garnet zoning profiles for the two samples are shown in Figs. 6c and d. The line traverses are interpreted as passing through the morphological centre, and therefore as recording the true radial chemical gradient, because the diameter of each of the grains roughly corresponds to that of the largest garnet crystal observed in hand specimen.

Garnet in the mica schist shows significant zoning in all end-member components (Fig. 6c). The asymmetry in zoning trends can be satisfactorily explained by variable amounts of garnet resorption along the rims. The overall outward increase of pyrope and almandine (except in the outer "left" margin), and decrease of Fe/(Fe+Mg) and spessartine, typifies growth zoning under upper greenschist and lower amphibolite facies conditions (e.g., Hollister, 1966; Tracy et al., 1976; Tracy, 1982). The sharp decrease in grossular and increase in spessartine in the outer garnet rim are attributed to modification during garnet consumption; a Mn reversal is generally believed to result from selective removal of Ca, Fe and/or Mg during garnet consumption, causing Mn to diffuse inwards (e.g., Grant and Weiblen, 1971; Yardley, 1977). The decrease in Ca may reflect its selective removal from garnet to provide the nutrients for growth of secondary plagioclase. (Determination of quantitative pressure and temperature estimates is part of work in progress by de Keijzer. Obtaining accurate peak metamorphic conditions, however, is difficult, if not impossible, because of the pronounced retrogression in unit QFM which resulted in, for example, re-equilibration of biotite composition.)

In contrast, none of the garnet end-member components in the eclogite sample are significantly zoned (Fig. 6d). The same observation has been recorded in other eclogite samples (Erdmer and Helmstaedt, 1983). In particular, the flat profile of spessartine ($0.00 < X_{Sps} < 0.02$) is striking.

DISCUSSION

INTERPRETATION OF THE GARNET ZONING RESULTS AND TECTONIC IMPLICATIONS

Dissimilar zoning trends, in particular of spessartine, are normally interpreted as being caused by different metamorphic/thermal histories rather than differences in reaction history and/or bulk rock composition. We propose the same interpretation for the two investigated samples, the strongest argument in favour of dissimilar thermal histories being the probable different degree of diffusional homogenization of garnet in each sample.

The extent of garnet modification by diffusion depends primarily on its size, the duration of heating, and the cooling rate (Spear, 1989; Florence and Spear, 1991). As suggested by these authors, no significant modification of growth zoning pattern is expected for 1–2 mm size garnets that experienced a thermal maximum of ≤ 600°C and slow cooling (of the order of 1–3°C/Ma). This appears appropriate for garnet in the mica schist. However, diffusional homogenization of growth zoning (e.g., Grant and Weiblen, 1971; Tracy et al., 1976; Tracy, 1982; Spear, 1989) of < 1 mm garnets is expected to be significant, if not complete, after the garnets have been subjected to temperatures > 600°C for any geologically significant time (Spear, 1989; Florence and Spear, 1991). The estimated peak temperature of the Last Peak eclogite is ~625°C (Erdmer et al., 1998). We therefore attribute the flat internal profiles in the eclogite primarily to diffusional homogenization at or near the peak temperature, similar to that proposed for eclogitic garnets elsewhere (e.g., Bocchio et al., 1985; Carlson and Schwarze, 1997). The lack of zoning

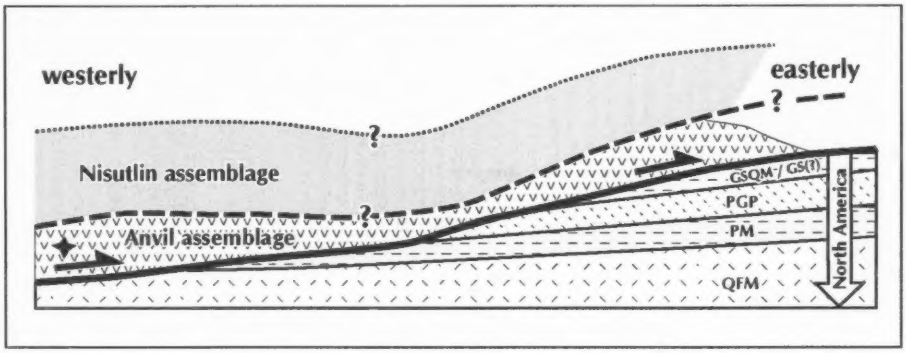

Figure 7. Idealized diagram showing easterly directed ductile thrusting of the Nisutlin and Anvil assemblages onto North America. The nature of the contact between the Nisutlin and Anvil assemblages is undetermined (see discussion for details).

in the garnet (comprising about half the rock volume) in the eclogite sample could be explained if eclogite garnet formed in a fraction of the time that it took for garnet to grow in the mica schist. This explanation, however, is considered unrealistic. Nor is the ~0.5 mm difference in garnet radius believed to be capable of explaining the difference in the amount of diffusional homogenization; the eclogite is interpreted as having experienced a higher maximum temperature than the mica schist.

It is considered unlikely that the flat spessartine profile in the eclogite represents a growth phenomenon. A "bell shape" spessartine profile is generally considered a good monitor of garnet growth zoning. It has been interpreted as marking the strong partitioning of Mn into garnet relative to matrix phases such as chlorite and biotite (Hollister, 1966; Tracy, 1982; Spear, 1989), and is therefore expected to occur in both pelitic and mafic bulk rock compositions. This is the case in the Cassiar Terrane. There, garnet in both amphibolite dykes and their micaceous host rocks have "bell shaped" spessartine zoning (de Keijzer, unpublished data,1998). Thus, the fact that the eclogite is the only rock in which spessartine is unzoned, suggests that significant diffusional homogenization has occurred, and that it is restricted to the eclogite.

Given the proximity of the two samples (~500 m apart) and their probable different thermal regimes, the simplest explanation, in agreement with all observations, is that a structural contact exists between the Last Peak eclogite and garnet-bearing quartzofeldspathic schist and pelite of unit QFM, to the west of it. In other words the eclogite is best interpreted as being exotic with respect to the QFM.

THE STRUCTURAL SETTING OF THE LAST PEAK ECLOGITE: REGIONAL CONSIDERATIONS

Based on kinematic observations, de Keijzer et al. (in press) proposed easterly directed thrusting of the Anvil and Nisutlin assemblages onto North America (Fig. 5). According to them, the Last Peak eclogite is situated in the hanging wall, only a few hundred metres above the basal (ductile) thrust/obduction boundary (Fig. 5), and unit QFM is part of the footwall sequence. This interpretation is in good agreement with the metamorphic data described above.

Supporting evidence for the location of, and easterly movement on, the basal thrust is provided by the distribution of rock units in the study area. Mafic and ultramafic rocks (units GG and SU) are found in both the western Teslin zone and east of the d'Abbadie fault (klippe in Fig. 2) which suggests they are the same units on opposite limbs of the Grizzly synform. Similarly, metasedimentary quartzofeldspathic schist and pelite west of the (ultra)mafic rocks in the western Teslin zone lithologically resemble the rocks in the northeastern portion of the Cassiar Terrane (e.g., typically > 40 cm wide quartzofeldspathic layers; similar modal abundances of major constituents; very rare marble layers). These rocks are shown as unit QFM in Fig. 2. In the western Teslin zone, the mafic rocks and unit QFM are in direct contact. East of the d'Abbadie fault, however, unit QFM and the mafic rocks are separated from one another by a succession dominated by garnet-rich pelite, marble, and graphite-bearing siliceous schists (units PM, PGP, and GSQM in Fig. 2) which structurally overlie unit QFM. Therefore, the distribution of rock types within the study area supports the model of easterly directed thrusting, with the basal thrust cutting up-section to the east, carrying the mafic rocks at the base of the hanging wall (Fig. 7). This is consistent with kinematic indicators in the western Teslin zone which record easterly movement of the hanging wall rocks during amphibolite facies regional metamorphism (de Keijzer et al., in press).

Figure 7 also illustrates that, prior to F_3 folding, the first-order distribution of rock packages was, from low to high structural level, North America, Anvil assemblage, and Nisutlin assemblage. Not shown in Fig. 7 are F_1-F_2 transposition folds, which result in a significantly more complicated geometrical framework at the km-scale (and smaller). The first-order sequence contrasts with that proposed by Tempelman-Kluit (1979), Hansen (1988; Anvil assemblage referred to as Slide Mountain Terrane), Hansen (1990; Anvil assemblage referred to as Teslin-Taylor Mountain Terrane), Hansen et al. (1991), and Stevens et al. (1996). These workers position the Anvil assemblage above the Nisutlin assemblage. However, we believe that just as recognition of the Grizzly synform has necessitated reinterpretation of the "inverted metamorphic gradient" it also necessitates re-evaluation of earlier tectonic reconstructions.

AMPHIBOLITIZATION OF THE LAST PEAK ECLOGITE

S_T in the western Teslin zone, in the klippe, and in the Cassiar Terrane, is interpreted by de Keijzer et al. (in press) as having accommodated larger shear strain than S_T in the eastern Teslin zone. This interpretation is based on the marked parallelism of L_M and F_1-F_2 hinges in these areas, a phenomenon not observed in the eastern Teslin zone (see de Keijzer et al., in press, for a more detailed explanation). Importantly, the more strongly sheared rocks are spatially associated with the interpreted basal thrust (Fig. 5a, b).

The Last Peak eclogite occurs within the high strain zone at the base of the hanging wall. It experienced a pervasive synkinematic amphibolite facies overprint, common to many eclogites worldwide (e.g., Bocchio et al., 1985; Klápová et al., 1998) and only a few relatively pristine eclogite relicts are preserved in low strain domains. Amphibolitization (hydration) of eclogite requires the introduction of fluids. Hydration of the eclogite is likely to have occurred since shear zones (i.e., the basal ductile thrust) commonly act as conduits for fluid (e.g., Beach, 1976, 1980; Brodie and Rutter, 1985). The fluids were conceivably derived from prograde dehydration reactions in the (dominantly micaceous) footwall rocks during thrusting.

RELATIONSHIPS BETWEEN THE LAST PEAK ECLOGITE AND OTHER HANGING-WALL ROCKS

Given the strong syn-kinematic medium-pressure regional metamorphic overprint (formation of Ca- amphibole + oligoclase + sphene + clinozoisite), it is unclear what portion of unit GG in the study area has experienced an earlier high pressure metamorphism similar to that of the Last Peak eclogite. In other words, the question has to be asked as to whether the eclogite is in-situ with respect to unit GG, and most of the evidence of high-pressure metamorphism has been obliterated, or whether it, and possible other volumetrically insignificant eclogite "blocks," were tectonically incorporated with lower grade rocks of unit GG after high-pressure metamorphism.

Concerning the greenschist facies Yukon-Tanana Nisutlin rocks further east of unit GG in the Teslin zone, no study has produced any evidence for a link between structure and/or metamorphism in the Nisutlin rocks and eclogite facies deformation and metamorphism. This is consistent with other studies (e.g., Erdmer and Helmstaedt, 1983; Mortensen, 1992; Foster et al., 1994; Erdmer et al., 1998) over a large area of the Yukon-Tanana Terrane, none of which have produced evidence of high-pressure metamorphism except in isolated lenses. Moreover, the nature of the contact between the Anvil and Nisutlin assemblages is a topic of continuing debate (see discussions by Mortensen, 1992 and Stevens et al., 1996). Some workers (e.g., Hansen et al., 1991) envisage this contact as a terrane boundary, juxtaposing the Teslin-Taylor Mountain Terrane, correlative with the Anvil assemblage, and the Nisutlin Terrane. Others (e.g., Mortensen and Jilson, 1985; Mortensen, 1992; Murphy, 1998) have interpreted similar rocks in the Finlayson Lake area (see Fig. 1) as part of transposed Yukon-Tanana stratigraphy. Importantly, in the western Teslin zone, the contact between Anvil and Nisutlin rocks is delineated by a narrow zone of graphite-rich schist and marble (Fig. 2). It is believed that these rock types were significantly weaker (easy slip zones) than the predominant rock types in both the Anvil and Nisutlin assemblages (see Fig. 2) during most of the ductile deformation history. The fact that graphite-rich schist throughout the area mostly contains a single pervasive foliation (in contrast to the multiple generations of fabric development preserved in the Nisutlin rocks; de Keijzer et al., in press) can be attributed to transposition being more complete in the weaker rocks. Despite the fact that no regionally significant structural or metamorphic breaks have been observed across the graphite-rich schist and/or marble units (de Keijzer et al., in press; Stevens et al., 1996), it is nevertheless possible that these rocks in the western Teslin zone represent a pre- to early syn-F_1 localized high strain/fault zone. However, because of the intensity of transposition, the nature of the contact between the Anvil and Nisutlin assemblages is obscured and impossible to interpret definitively based on existing field data. In summary, we see no reason to assume a relationship between the Nisutlin assemblage and the Last Peak eclogite and therefore consider the latter exotic with respect to the former.

CONCLUSIONS

Building on earlier structural and regional data of Erdmer and Helmstaedt (1983) and de Keijzer et al. (in press), the contrast in metamorphic grade of the Last Peak eclogite and amphibolite and greenschist facies metasedimentary rocks to the west and east of it, respectively, can be explained in terms of juxtaposition of high-pressure and low- to medium-pressure rocks after eclogite facies metamorphism. This interpretation is supported here by profound differences between garnet zoning profiles in an eclogite sample and a mica schist collected ~500 m west of the eclogite. The proposed exotic nature of the eclogite explains why evidence of high-pressure metamorphism is restricted to one small area in the Teslin zone. Further, the proposition that the eclogite is situated at the base of the obducted Anvil and Nisutlin rocks (cf. de Keijzer et al., in press) satisfactorily explains why only a few relicts of high-pressure rocks have been preserved in the western Teslin zone; it was incorporated in the ductile thrusting process and therefore was prone to amphibolitization during fluid-assisted deformation. It is unclear whether the Last Peak eclogite is exotic with respect to other Anvil rocks or not.

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REFERENCES

Beach, A., 1976. The interrelations of fluid transport, deformation, geochemistry and heat flow in early Proterozoic shear zones in the Lewisian complex. Philosophical Transactions of the Royal Society London, vol. A280, p. 569-604.

Beach, A., 1980. Retrogressive metamorphic processes in shear zones with special reference to the Lewesian complex. Journal of Structural Geology, vol. 2, p. 257-263.

Bocchio, R., Liborio, G. and Mottana, A., 1985. Petrology of the amphibolitized eclogites of Gorduno, Lepontine Alps, Switserland. Chemical Geology, vol. 50, p. 65-86.

Brodie, E.H. and Rutter, K.H., 1985. The permeation of water into hydrating shear zones. In Advances in Physical Geochemistry, vol. 4. A.B. Bruce and D.C Rubie (eds). Springer-Verlag, New York.

Carlson, W. and Schwarze, E., 1997. Petrological significance of prograde homogenization of growth zoning in garnet: an example from the Llano Uplift. Journal of Metamorphic Geology, vol. 15, p. 631-644.

de Keijzer, M. and Williams, P.F., 1997. A new view on the structural framework of the Teslin zone, south-central Yukon. *In:* Slave-Northern Cordilleran Lithospheric Evolution (SNORCLE) Workshop. Compiled by F. Cook and P. Erdmer. University of Calgary, Calgary, Lithoprobe Report, vol. 56, p. 96-102.

de Keijzer, M., Williams, P.F. and Brown, R.L., (in press). Kilometre-scale folding in the Teslin zone, northern Canadian Cordillera, and its tectonic implications for the accretion of the Yukon-Tanana Terrane to North America. Canadian Journal of Earth Sciences.

Erdmer, P., 1985. An examination of the cataclastic fabrics and structures of parts of the Nisutlin, Anvil and Simpson allochthons, central Yukon: test of the arc-continent collision model. Journal of Structural Geology, vol. 7, p. 57-72.

Erdmer, P., 1992. Eclogite rocks in the St. Cyr klippe, and their tectonic significance. Canadian Journal of Earth Sciences, vol. 29, p. 1296-1304.

Erdmer, P. and Helmstaedt, H., 1983. Eclogite from central Yukon: a record of subduction at the western margin of ancient North America. Canadian Journal of Earth Sciences, vol. 20, p. 1389-1408.

Erdmer, P., Ghent, E.D., Archibald, D.A. and Stout, M.Z., 1998. Paleozoic and Mesozoic high-pressure metamorphism at the margin of ancestral North America in central Yukon. Geological Society of America, Bulletin, vol. 110, p. 615-629.

Ernst, W.G., 1971. Metamorphic zonations on presumably subducted lithospheric plates from Japan, California, and the Alps. Contributions to Mineralogy and Petrology, vol. 34, p. 43-59.

Florence, F.P. and Spear, F.S., 1991. Effects of diffusional modification of garnet growth zoning on P-T calculations. Contributions to Mineralogy and Petrology, vol. 107, p. 487-500.

Foster, H.L., Keith, T.E.C. and Menzie, W.D., 1994. Geology of the Yukon-Tanana area of east-central Alaska. *In:* The Geology of Alaska. Plafker, G. and Berg, H.C. (editors). Geological Society of America, Boulder, Colorado, vol. G-1, p. 205-240.

Gabrielse, H. 1985. Major dextral transcurrent displacements along the Northern Rocky Mountain Trench and related lineaments in north-central British Columbia. Geological Society of America, Bulletin, vol. 96, p. 1-14.

Gordey, S.P., 1981. Stratigraphy, structure and tectonic evolution of southern Pelly Mountains in the Indigo Lake area, Yukon Territory. Geological Survey of Canada, Bulletin 318, p. 41.

Grant, J.A. and Weiblen, P.W., 1971. Retrograde zoning in garnet near the second sillimanite isograd. American Journal of Science, vol. 270, p. 281-296.

Hansen, V.L., 1988. A model for terrane accretion: Yukon-Tanana and Slide Mountain terranes, northwest North America. Tectonics, vol. 7, p. 1167-1177.

Hansen, V.L., 1989. Structural and kinematic evolution of the Teslin suture zone, Yukon: record of an ancient transpressional margin. Journal of Structural Geology, vol. 11, p. 717-733.

Hansen, V.L., 1990. Yukon-Tanana Terrane: A partial acquittal. Geology, vol. 18, p. 365-369.

Hansen, V.L., 1992. P-T evolution of the Teslin suture zone and Cassiar tectonites, Yukon, Canada: evidence for A- and B-type subduction. Journal of Metamorphic Geology, vol. 10, p. 239-263.

Hansen, V.L. and Dusel-Bacon, C., 1998. Structural and kinematic evolution of the Yukon-Tanana upland tectonites, east-central Alaska: A record of late Paleozoic to Mesozoic crustal assembly. Geological Society of America, Bulletin, vol. 110, p. 211-230.

Hansen, V.L., Heizler, M.T. and Harrison, T.M., 1991. Mesozoic thermal evolution of the Yukon-Tanana composite terrane: New evidence from $^{40}Ar/^{39}Ar$ data. Tectonics, vol. 10, p. 51-76.

Hollister, L.S., 1966. Garnet zoning: An interpretation based on the Rayleigh fractionation model. Science, vol. 154, p. 1647–1651.

Klápová, H., Konopásek, J. and Schulman, K., 1998. Eclogites from the Czech part of the Erzgebirge: multi-stage metamorphic and structural evolution. Journal of the Geological Society, London, vol. 155, p. 567–583.

Mortensen, J.K., 1992. Pre-mid-Mesozoic tectonic evolution of the Yukon-Tanana Terrane, Yukon and Alaska. Tectonics, vol. 11, p. 836–853.

Mortensen, J.K. and Jilson, G.A., 1985. Evolution of the Yukon-Tanana Terrane: Evidence from southeastern Yukon Territory. Geology, vol. 13, p. 806–810.

Murphy, D.M., 1998. Stratigraphic framework for syngenetic mineral occurrences, Yukon-Tanana Terrane south of Finlayson Lake: A progress report. *In:* Yukon Exploration and Geology 1997, Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 51-58.

Spear, F.S., 1989. Petrologic determination of metamorphic pressure-temperature-time paths. *In:* Pressure-Temperature-Time paths. F.S. Spear and S.M. Peacock (eds). American Geophysical Union, Short Course in Geology, vol. 7, p. 1–55.

Stevens, R.A., 1994. Structural and tectonic evolution of the Teslin tectonic zone, Yukon: A doubly-vergent transpressive shear zone. Ph.D. thesis, University of Alberta, Edmonton, 252 p.

Stevens, R.A. and Erdmer, P., 1996. Structural divergence and transpression in the Teslin tectonic zone, southern Yukon Territory. Tectonics, vol. 15, p. 1342–1363.

Stevens, R.A., Erdmer, P., Creaser, R.A. and Grant, S.L., 1996. Mississippian assembly of the Nisutlin assemblage: Evidence from primary contact relationships and Mississippian magmatism in the Teslin tectonic zone, part of the Yukon-Tanana Terrane of south-central Yukon. Canadian Journal of Earth Sciences, vol. 33, p. 103–116.

Tempelman-Kluit, D.J., 1979. Transported cataclasite, ophiolite and granodiorite in Yukon: evidence of arc–continent collision. Geological Survey of Canada, Paper 79–14, p. 27.

Tracy, R.J., 1982. Compositional zoning and inclusions in metamorphic minerals. Reviews in Mineralogy, vol. 10, p. 355–394.

Tracy, R.J., Robinson, P. and Thompson, A.B., 1976. Garnet composition and zoning in the determination of temperature and pressure of metamorphism, central Massachusetts. American Mineralogist, vol. 61, p. 762–775.

Wheeler, J.O. and McFeely, P., 1991. Tectonic assemblage map of the Canadian Cordillera and adjacent parts of the United States of America. Geological Survey of Canada, Map 1712A, 1:2 000 000 scale.

Wheeler, J.O., Brookfield, A.J., Gabrielse, H., Monger, J.W.H., Tipper, H.J. and Woodworth, G.J., 1991. Terrane map of the Canadian Cordillera. Geological Survey of Canada, Map 1713A, 1:2 000 000 scale.

Williams, P.F., 1983. Large scale transposition by folding in northern Norway. Geologische Rundschau, vol. 72, p. 589–604.

Yardley, B.W.D., 1977. An empirical study of diffusion in garnet. American Mineralogist, vol. 62, p. 793–800.

Jurassic plate motions of the Stikine Terrane, southern Yukon: A paleomagnetic and geothermometric study of the Teslin Crossing Pluton (105E/7)

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ABSTRACT

The ~177 Ma Teslin Crossing Pluton was studied paleomagnetically to determine the post-Early Jurassic tectonic motions of the northern Stikine Terrane. There are few published tectonic estimates for rock units older than mid-Cretaceous time for the area. The pluton is dominantly monzonite with syenite patches and a more mafic border phase. To the north and south of the pluton are spatially associated sill complexes that are chemically similar and coeval with the pluton. Acceptable geothermometry values from three sites suggest at the 95% confidence level that the pluton has not been tilted since crystallization. This is supported by the circular outcrop pattern of the pluton and the flat-lying host rocks. The pluton was sampled for paleomagnetic analysis at thirteen sites and six sites were sampled in sills from south of the pluton. Fifteen of the nineteen sites give a well-defined mean characteristic remanent magnetic (ChRM) direction for the pluton and sills at a declination = 6°, inclination = 78°, cone of 95% confidence = 9° and precision parameter = 20, corresponding to a paleopole at 110.6°W and 84.3°N (dp = 16°, dm = 17°). It suggests that the northern Stikine Terrane has undergone 21.1° ± 7.4° of net southward translation, or translation away from the reference pole, with respect to the North American craton since Middle Jurassic time. The estimate also suggests a net clockwise rotation of 33° ± 18°. This translation estimate is similar to that for the coeval Fourth of July Batholith that is part of the neighbouring Cache Creek Terrane and indicates that the Stikine and Cache Creek Terranes were proximal to one another at that time. Further, it suggests that these two terranes were offshore of the North American craton, and were carried eastward by the Farallon Plate through the Jurassic.

RÉSUMÉ

Le paléomagnétisme du pluton de Teslin Crossing, vieux d'environ 177 Ma, a été étudié afin de déterminer les mouvements du terrane de Stikine septentrional postérieurs au Jurassique précoce. Il n'existe que peu d'estimations tectoniques publiées pour les unités lithostratigraphiques plus anciennes que le Crétacé moyen dans la région. Le pluton est surtout monzonitique avec des morceaux syénitiques et une bordure présentant une phase davantage mafique. Au nord et au sud du pluton on trouve des complexes filoniens associés qui sont chimiquement similaires et contemporains du pluton. Des valeurs géothermiques acceptables relevées en trois emplacements suggèrent, au niveau de confiance de 95 %, que le pluton n'a pas été basculé depuis la cristallisation, ce qui est appuyé par la forme circulaire de l'affleurement du pluton et les roches encaissantes gisant à plat. Des échantillons à soumettre à l'analyse paléomagnétique ont été recueillis en treize emplacements et desquels six dans les filons-couches ont été échantillonnés au sud du pluton. En quinze des dix-neuf emplacements on obtient une direction ChRM moyenne pour le pluton et les filons-couches à une déclinaison = 6%, à une inclinaison = 78%, à un cône de confiance à 95 % = 9% et pour un paramètre de précision = 20, ce qui correspond à un paléopôle par 110,6%W et 84,3%N (dp = 16%, dm = 17%). Cela suggère que la partie nord du terrane de Stikine a subi une translation nette vers le sud de 21,1% Å 7,4%, ou une translation l'éloignant du pôle de référence, par rapport au craton nord-américain depuis le Jurassique moyen. L'estimation suggère également une rotation nette dans le sens horaire de 33% Å 18%. Cette translation estimée est similaire à celle du batholite Fourth of July contemporain, qui se trouve dans le terrane avoisinant de Cache Creek, et indique que les terranes de Stikine et de Cache Creek étaient proches l'un de l'autre à cette époque. Il est de plus suggéré que ces deux terranes se trouvaient au large du craton nord-américain et qu'ils ont été portés vers l'est par la plaque Farallon pendant le Jurassique.

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INTRODUCTION

The Teslin Crossing Pluton was studied paleomagnetically to determine the tectonic motion of the northern Canadian Cordillera since Middle Jurassic time. It is one of six rock units studied in the northern British Columbia-southern Yukon area as part of a Ph.D. dissertation by Harris (1998) and one of a number of studies undertaken by the Paleomagnetic Laboratory at the University of Windsor as part of the LITHOPROBE-SNORCLE project (Cook and Erdmer, 1995, 1996).

Tectonic motions of the Canadian Cordillera are well constrained for the Paleogene and the Cretaceous periods, but are less well known for Jurassic or earlier times. The Teslin Crossing Pluton is the third rock unit of Jurassic or older age that has been paleomagnetically studied in the northern Canadian Cordillera. The 172 Ma Fourth of July Batholith from the Cache Creek Terrane in northern British Columbia has yielded acceptable results (Harris, 1998), but the tectonic interpretation from results of Paleozoic mafic volcanic rocks and carbonate units in the same area are inconclusive (Cole et al., 1992).

The Teslin Crossing Pluton is located ~65 km north-northeast of Whitehorse (Fig. 1) where it has intruded into the Stikine Terrane. The pluton has yielded isotopic Middle Jurassic ages (Stevens et al., 1982; Tempelman-Kluit, 1984) and has been explored for copper and gold (Pangman and VanTassell, 1972; Hart, 1996).

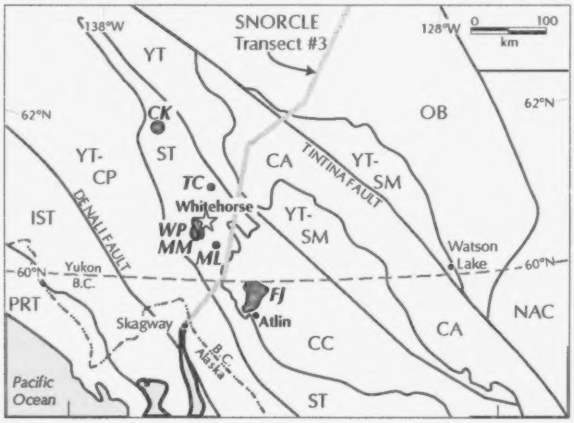


Figure 1. *Location of the Teslin Crossing Pluton and other plutons and the tectonic subdivisions of the northern Cordillera. Terrane boundaries are from Wheeler and McFeely (1991).*

CA - Cassiar Terrane
CC - Cache Creek Terrane
CK - Carmacks volcanics
FJ - Fourth of July Batholith
IST - Insular superterrane
ML - Mount Lorne Stock
MM - Mount McIntyre Pluton
NAC - North American craton
OB - Omineca fold belt
PRT - Pacific Rim terranes
ST - Stikine Terrane
TC - Teslin Crossing Pluton
WP - Whitehorse Pluton
YT - Yukon-Tanana Terrane
YT-CP - Yukon-Tanana-Coast Plutonic Complex
YT-SM - Yukon-Tanana-Slide Mountain terranes

This report presents paleomagnetic data for the Teslin Crossing Pluton and tectonic implications derived from them. Further, it presents biotite geothermometry data used to assess the possibility of post-magnetization tilting, and make tectonic corrections to the paleomagnetic data as necessary.

REGIONAL GEOLOGIC SETTING

The Stikine Terrane is the largest of the exotic terranes that have been accreted to the western margin of the North American craton. The terrane consists of an Upper Paleozoic volcanic arc basement that is overlain by the Middle to Late Triassic Lewes River volcanic arc. Intrusive-rich clastic sedimentary rocks of the Jurassic Laberge Group overlie volcanic-rich detritus and carbonate units of the Lewes River Group. The two sedimentary packages are up to seven kilometres thick and were accumulated in a marginal basin known as the Whitehorse Trough (Hart, 1996, 1997). The Middle Jurassic strata that host the Teslin Crossing Pluton are largely flat-lying (Fig. 2).

LOCAL GEOLOGY

The Teslin Crossing Pluton forms a high-standing topographic region above the recessive Middle Jurassic Tanglefoot Formation of the Laberge Group. The Tanglefoot Formation is dominated by fissile, black, well-bedded, carbonaceous, variably limy, poorly-indurated shale and siltstone with lesser amounts of thin chert-rich sandstone beds. The sedimentary rocks immediately adjacent to the pluton are tilted but all dips are away from the pluton which suggests local deformation due to forceful intrusion of the magma. The moderately dipping rocks on its eastern margin likely acquired their tilt during Cretaceous and younger faulting.

The host rocks become shallowly dipping to horizontal within a couple of kilometres of the pluton. The intrusive's contacts are steep and control topography. The pluton is roughly circular in plan and is exposed over an area of ~60 km^2, but its strongly positive magnetic anomaly suggests a slightly increased area of ~100 km^2 just below the surface. The eastern margin of the pluton is cut by a splay of the Chain Fault, a through-going northwest-trending fault system (Fig. 2).

To the northwest, and just to the south of the pluton, are sets of monzodioritic sills that are spatially and chemically associated with the pluton. No volcanic units or other extensive intrusive suites have been recognized to be in association with the pluton.

The Teslin Crossing Pluton is crudely zoned, consisting of a central phase, a border phase and the associated dyke swarms and sills (Fig. 2). The dominant rock type of the central phase is

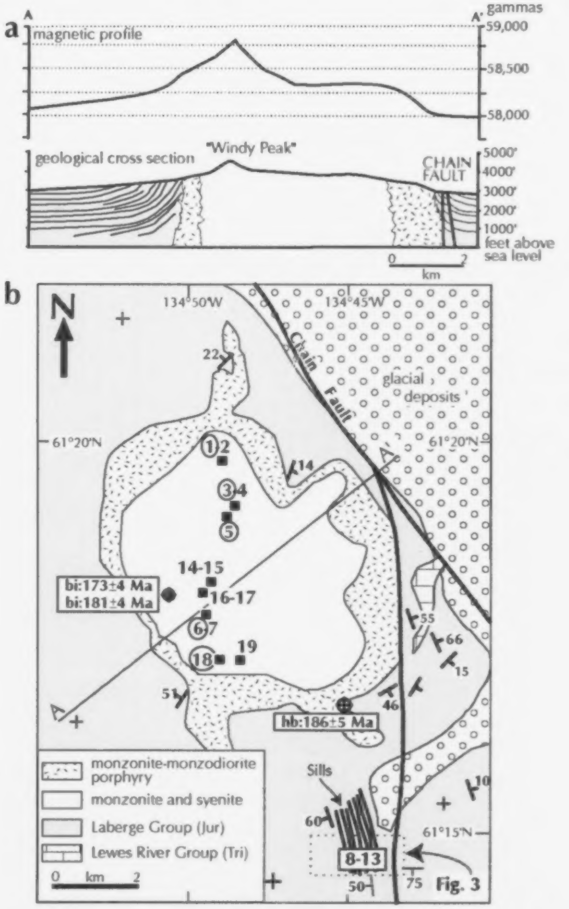

a
A
A'
magnetic profile
gammas
59,000
58,500
58,000
geological cross section
"Windy Peak"
CHAIN FAULT
5000'
4000'
3000'
2000'
1000'
feet above sea level
0 2
km
b
N
134°50'W
134°45'W
Chain Fault
glacial deposits
61°20'N
61°20'N
22
14
①2
③4
⑤
14-15
16-17
bi:173±4 Ma
bi:181±4 Ma
⑥7
⑱
19
51
55
66
15
46
hb:186±5 Ma
Sills
60
8-13
10
61°15'N
50
75
Fig. 3
monzonite-monzodiorite porphyry
monzonite and syenite
Laberge Group (Jur)
Lewes River Group (Tri)
0 km 2

Figure 2. a) *Magnetic profile and geological cross section,* ***b)*** *local geology of the Teslin Crossing Pluton after Hart (1996) with sampling sites (solid squares). Circled numbers are geothermometry sites; and circles with crosses are K-Ar date sites: bi-biotite, hb-hornblende; and crosses near the edges of the map indicate flat-lying strata.*

a medium to light greyish-pink monzonite. The mineralogy consists of euhedral medium-grained plagioclase in a matrix of finer-grained orthoclase, hornblende, clinopyroxene and magnetite. Secondary to the monzonite is a cross-cutting phase comprising leucocratic, dark pink syenite that consists of orthoclase and up to 10% plagioclase. Mafic minerals are generally lacking in this assemblage. Additionally, there are small plugs and dykes of leucocratic, light-pink, coarse-grained alkali feldspar syenite in the central phase which contain minor amounts of hornblende, clinopyroxene, plagioclase and magnetite in addition to the orthoclase. In all phases, the accessory minerals include titanite, apatite, biotite, hypersthene and rutile.

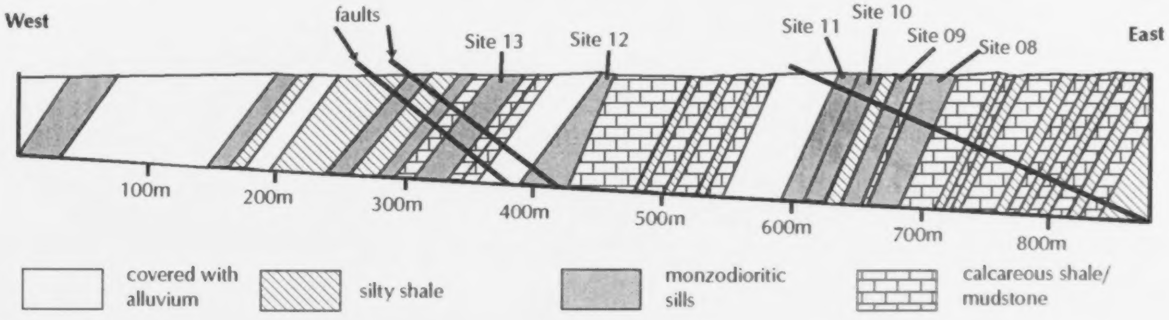
The border phase of the pluton is dominated by medium-grey porphyritic and granophyric monzodiorite to monzonite. This phase consists of euhedral plagioclase and clinopyroxene within a matrix of orthoclase, hornblende and plagioclase. Accessory minerals include magnetite, apatite, titanite, pyroxene and pyrite.

The sills to the south of the pluton occur in well-bedded black shales, with both rock units dipping to the west at 54° to 64° (Fig. 3). The sills are 3 to 15 m thick and have strike lengths of several kilometres (Hart, 1996). Hornfelsed country rock next to the sills is uncommon, and the sills have only a narrow (<1 cm) chilled margin. The chemistry and the mineral assemblage of the sills are similar to the border phase of the pluton although the sills are finer grained, slightly more mafic and locally trachytic.

Preliminary geochemical analyses indicate that the pluton is alkalic with fractionation trends toward a slightly sodium-rich end-member. Loss-on-ignition (LOI) values for the sills are slightly higher than for the pluton by ~1%, but are still low enough to indicate negligible alteration.

Three K-Ar age determinations from the pluton range from 173 to 186 Ma (Fig. 2; Stevens et al., 1982; Tempelman-Kluit, 1984). The two results from the central phase are from biotite, yielding values of 173 ± 4 and 181 ± 4 Ma, while the border phase

Figure 3. *Cross section of the sills that occur to the south of the pluton and sampling sites.*


West
faults
Site 13
Site 12
Site 11
Site 10
Site 09
Site 08
East
100m
200m
300m
400m
500m
600m
700m
800m
covered with alluvium
silty shale
monzodioritic sills
calcareous shale/ mudstone

yielded a value of 186 ± 5 Ma on hornblende. A preliminary U-Pb zircon value from one of the sills to the south of the pluton is 175.6 ± 2.0 Ma, based on the weighted $^{207}Pb/^{206}Pb$ age of two slightly discordant fractions (J. Mortensen, pers. comm. in Hart, 1996). The age of acquired magnetism, taken as 177 Ma, is the average of the two biotite K-Ar values within the central phase of the pluton where all the paleomagnetic samples were collected, and this is supported by the similar U-Pb age of the nearby comagmatic sills.

BIOTITE GEOTHERMOMETRY

The paleomagnetic data can be interpreted with confidence only if the paleohorizontal position of the rock units can be assertained. In sedimentary and volcanic rocks, bedding planes can be used to correct for any post-magnetization tilting, but within intrusive rocks natural visible indicators of a horizontal surface are rare. Recently, some paleomagnetic studies on plutons have utilized the Al-in-hornblende geobarometer to determine amounts of post-intrusive tilting (Ague and Brandon, 1992, 1996; Harris et al., 1996, 1997; Harris, 1998). Unfortunately, this geobarometric procedure could not be used on the Teslin Crossing Pluton because of the paucity, and altered character of the hornblende. Further, no other geobarometers could be used because of the mineral assemblage of the pluton. A possible alternative is suggested here, that of an isothermal surface provided by a geothermometer. Ideally, a small intrusive body will have a constant geothermal gradient above it that reflects the isothermal surface. Two geothermometers were available given the mineral assemblage of the pluton: the ternary feldspar method and the Ti-in-biotite method. The former method has many difficulties and assumptions in the temperature calculations (Essene, 1989) and, therefore, the latter method was used and is outlined here.

The Ti-in-biotite geothermometer is based on the observed phenomena that the concentration of Ti cations in biotite increases as temperature increases (LeBel, 1979). Similar qualitative observations have been made by other investigators (cf. Guidotti et al., 1977; Guidotti, 1984). The control conditions in the system include: Ti-saturation, indicated by the presence of a titaniferous mineral such as titanite or ilmenite; and, a constant Mg/Fe ratio of less than 2 which indicates a relatively constant oxygen fugacity. The original independent calibration of LeBel (1979) was based on three independently determined points in the temperature range of 400° to 800°C and a range of 0.2 to 0.5 Ti-cations per 22 (O, OH, F, Cl) anions. Two revised expressions have been developed as more data has been accumulated. Data for this report is based on the following quadratic equation (W.H. Blackburn, pers. comm.):

$$\text{temp } (\pm 50^\circ\text{C}) = 3047.6({}^{vi}\text{Ti})^2 - 626.19 \times {}^{vi}\text{Ti} + 348.93 \quad (r^2 = 0.99)$$

The geothermometer is not well-constrained and therefore the absolute temperatures are not considered very accurate. However, assuming the geothermal gradient was relatively uniform over the small Teslin Crossing Pluton as it cooled, then only the relative crystallization temperatures are necessary to determine any post-cooling tilting.

Polished thin sections were made of samples from five locations (Fig. 2) for electron microprobe analyses on biotite crystals. At least three analyses were done on a minimum of two biotite crystals per site. The procedures and microprobe operating parameters have been given in detail elsewhere (Harris et al., 1997; Harris, 1998). Only three of the five samples analysed gave reliable results, i.e., igneous cooling temperatures for biotite crystallization (TC 01, 05 and 18; Table 1; Fig. 4). The three values are not significantly different at the 95% confidence level, suggesting that the pluton has not been tilted. However, if all the data are considered, including sites 03 and 06, and averages are taken for the northern sites (01, 03 and 05) and the southern sites (06 and 18), the two averages suggest a potential tilt of 30° down to the north. This is not consistent with the horizontal bedding planes of the host rocks within a couple of kilometres from the pluton. Therefore, the bedding attitudes of the host rocks, the roughly circular shape of the pluton and the distribution of statistically similar magmatic biotite temperatures are accepted as evidence that there has not been any post-intrusive tilting.

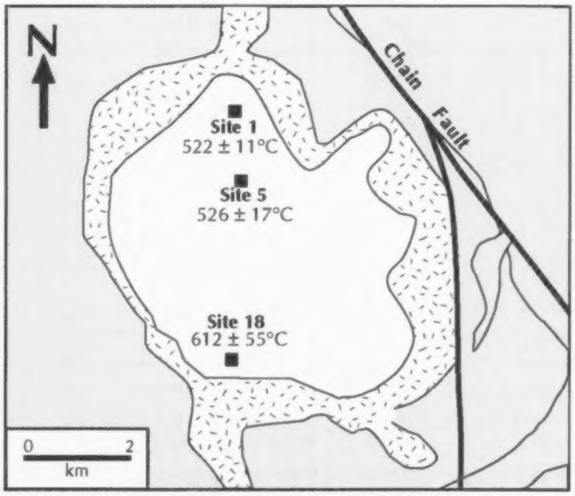


Figure 4. *Temperature data for the Teslin Crossing Pluton showing biotite geothermometry results (see legend in Fig. 2).*

Table 1. *Average biotite analyses with their 95% confidence limits and calculated temperatures for the Teslin Crossing Pluton. Structural formulae are normalized to 22 (O, OH, F, Cl) anions. N = number of samples in average; H_2O^* is back-calculated from the structural formula. Fe# = $Fe^{2+}/(Fe^{2+} + Mg)$; Temp is site-averaged temperature and standard deviation.*

Site	**TC01**	**TC03**	**TC05**	**TC06**	**TC18**
N	**3**	**3**	**4**	**3**	**6**
SiO_2	37.32 ± 0.02	37.31 ± 0.29	39.90 ± 0.37	39.35 ± 0.09	37.50 ± 0.19
TiO_2	3.22 ± 0.06	0.06 ± 0.03	3.32 ± 0.12	3.35 ± 0.10	4.10 ± 0.17
Al_2O_3	13.95 ± 0.11	21.99 ± 0.31	12.52 ± 0.52	12.65 ± 0.12	13.54 ± 0.15
Cr_2O_3	0.04 ± 0.03	0.01 ± 0.01	0.02 ± 0.02	0.00 ± 0.00	0.00 ± 0.00
FeO	15.48 ± 0.26	6.69 ± 0.74	13.90 ± 0.41	11.67 ± 0.21	17.25 ± 0.24
MnO	0.60 ± 0.05	0.37 ± 0.08	0.33 ± 0.08	0.27 ± 0.05	0.41 ± 0.07
MgO	15.23 ± 0.09	3.49 ± 0.39	16.26 ± 0.51	18.45 ± 0.06	13.75 ± 0.40
CaO	0.01 ± 0.00	22.86 ± 0.05	0.12 ± 0.07	0.00 ± 0.00	0.12 ± 0.16
Na_2O	0.30 ± 0.05	0.02 ± 0.01	0.17 ± 0.03	0.25 ± 0.01	0.23 ± 0.07
K_2O	9.16 ± 0.03	0.01 ± 0.01	8.94 ± 0.12	9.54 ± 0.11	9.10 ± 0.12
H_2O^*	3.69 ± 0.02	4.02 ± 0.04	3.32 ± 0.06	3.23 ± 0.01	3.41 ± 0.04
F	0.67 ± 0.02	0.10 ± 0.05	1.64 ± 0.11	1.87 ± 0.03	1.26 ± 0.09
Cl	0.02 ± 0.01	0.01 ± 0.01	0.03 ± 0.01	0.04 ± 0.01	0.09 ± 0.03
Total	**99.69**	**96.93**	**100.44**	**100.69**	**100.73**
Si	5.591 ± 0.014	5.497 ± 0.027	5.838 ± 0.045	5.717 ± 0.016	5.591 ± 0.014
^{iv}Al	2.416 ± 0.023	2.503 ± 0.027	2.139 ± 0.071	2.166 ± 0.019	2.380 ± 0.031
^{vi}Al	0.045 ± 0.031	1.316 ± 0.031	0.020 ± 0.035	0.000 ± 0.000	0.000 ± 0.000
^{iv}Ti	0.000 ± 0.000	0.000 ± 0.000	0.024 ± 0.029	0.117 ± 0.018	0.029 ± 0.017
^{vi}Ti	0.362 ± 0.006	0.067 ± 0.003	0.342 ± 0.040	0.249 ± 0.027	0.431 ± 0.034
Cr	0.005 ± 0.003	0.001 ± 0.001	0.002 ± 0.002	0.000 ± 0.001	0.000 ± 0.000
Fe^{2+}	1.937 ± 0.037	0.824 ± 0.094	1.701 ± 0.046	1.418 ± 0.026	2.151 ± 0.034
Mn	0.075 ± 0.006	0.046 ± 0.010	0.041 ± 0.010	0.033 ± 0.006	0.052 ± 0.009
Mg	3.396 ± 0.020	0.766 ± 0.083	3.545 ± 0.117	3.995 ± 0.017	3.055 ± 0.083
Ca	0.001 ± 0.001	3.608 ± 0.014	0.019 ± 0.011	0.001 ± 0.001	0.019 ± 0.025
Na	0.088 ± 0.013	0.006 ± 0.002	0.049 ± 0.008	0.071 ± 0.001	0.065 ± 0.022
K	1.748 ± 0.010	0.003 ± 0.002	1.669 ± 0.020	1.769 ± 0.019	1.731 ± 0.026
OH	3.679 ± 0.008	3.951 ± 0.023	3.237 ± 0.051	3.129 ± 0.012	3.387 ± 0.041
F	0.316 ± 0.012	0.047 ± 0.022	0.757 ± 0.051	0.860 ± 0.013	0.592 ± 0.041
Cl	0.006 ± 0.002	0.002 ± 0.002	0.006 ± 0.001	0.011 ± 0.001	0.022 ± 0.007
Fe#	36.33 ± 0.33	51.80 ± 5.53	32.43 ± 1.33	26.20 ± 0.28	41.33 ± 1.03
Temp	**522 ± 11°C**	**340 ± 11°C**	**526 ± 17°C**	**369 ± 27°C**	**612 ± 55°C**

PALEOMAGNETISM

Nineteen sites were sampled, including thirteen sites within the central phase of the pluton and six sites from the monzodioritic sills to the south, where accessable by helicopter (Fig. 2). Samples consisted of 2.5 cm diameter drill cores that were up to 10 cm in length and were later cut into paleomagnetic specimens of standard 2.2 cm height. Additional details on the paleomagnetic procedures can be found in Harris et al. (1996) and Harris (1998).

The natural remanent magnetization (NRM) was measured for each of the 207 specimens on an automated Canadian Thin Films (CTF) DRM-420 cryogenic magnetometer. The specimens from the pluton have a median NRM intensity of 1.0 x 10^0 amperes per metre (A/m) and the specimens from the sills have a median NRM intensity of 3.0 x 10^{-2} A/m. Two specimens from each site that had average declination, inclination and intensity were selected as pilot specimens. One pilot specimen was demagnetized in an alternating field (AF) following a schedule of 10 steps from 5 to 130 milliTesla (mT), with the specimen being measured after each demagnetization step. The second pilot specimen was thermally demagnetized on a schedule of 12 steps from 200°C to 585°C, with some specimens being further demagnetized up to 660°C. Both demagnetization methods yielded similar characteristic remanent magnetization (ChRM) directions. Therefore the remaining specimens from the sites were AF demagnetized in five to seven steps because this was the more efficient method. However, some specimens were subjected to several steps of thermal demagnetization after the AF demagnetization to completely isolate their ChRM direction.

Thermal decay curves of the specimens from the central phase of the pluton show that either titanomagnetite or magnetite is

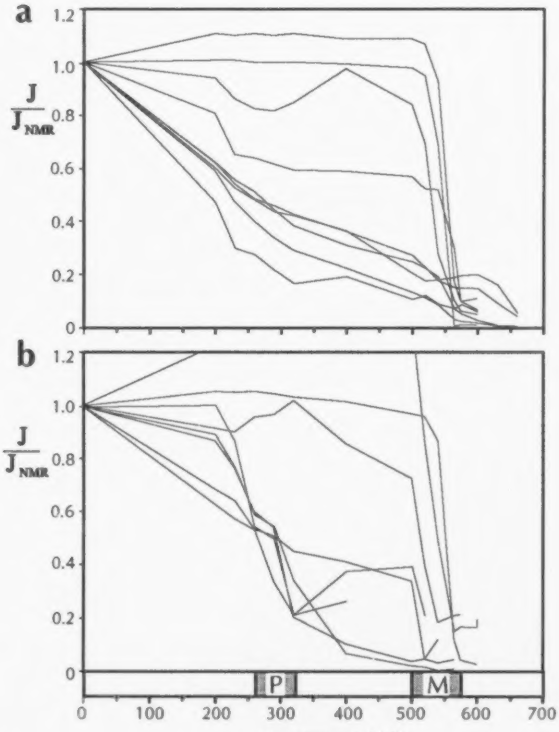


Figure 5. Representative thermal decay curves for specimens from the Teslin Crossing Pluton and sills. ***a)*** *Granitoid specimens from the central phase.* ***b)*** *Specimens from the sills. Preferred unblocking temperatures diagnostic of pyrrhotite and magnetite are shown at the bottom by the P and M, respectively.*

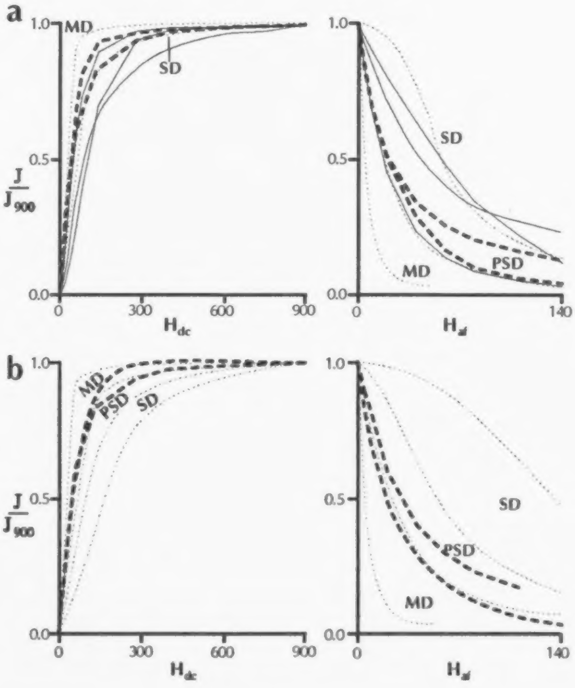


Figure 6. *Representative SIRM acquisition and decay curves for the Teslin Crossing Pluton. The H_{dc} and H_{af} axes are measured in mT and the y-axis is the measured intensity as a ratio of the saturation intensity (at 900 mT). The thin dashed reference curves in* ***a)*** *are for single domain (SD), pseudosingle domain (PSD) and multidomain (MD) magnetite. The reference curves in* ***b)*** *are for single domain (SD), pseudosingle domain (PSD) and multidomain (MD) pyrrhotite. The solid curves are specimens from the central phase of the pluton and the heavy dashed lines are for specimens from the sills.*

the dominant carrier of their magnetization (Fig. 5a). Magnetite decay curves show rapid decreases in relative intensity between 500° and 570°C, whereas titanomagnetite curves have a more gradual decay. Pyrrhotite, titanomagnetite or magnetite carries the magnetization of the specimens from the sills (Fig. 5b), with the pyrrhotite curves showing rapid relative intensity decay between 270° and 320°C.

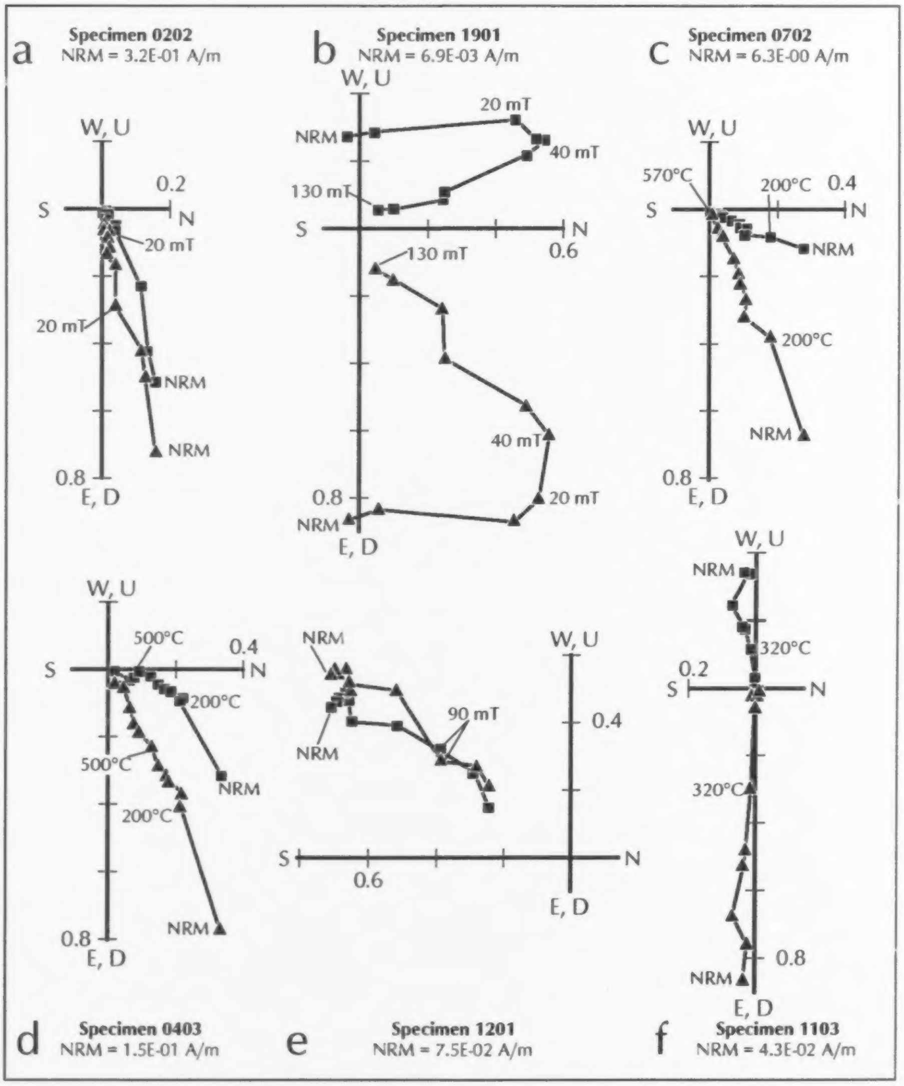


*Figure 7. Orthogonal step demagnetization plots showing the changes in declination and inclination relative to intensity changes. Plots **a)** to **d)** show selected specimens from the central phase of the Teslin Crossing Pluton. Plots **e)** and **f)** show selected specimens from the sills. Squares are in the N-E-S-W plane and the triangles are in the Up(U)-N-Down(D)-S plane.*

Saturation isothermal remanent magnetization (SIRM) testing was done on 11 of the AF pilot specimens to define better the domain size of the magnetic carriers. The specimens were subjected to a direct magnetic field in eleven steps from 10 to 900 mT, then AF demagnetized in seven steps from 10 to 140 mT. The specimens from the pluton show single, pseudosingle and multidomain magnetite properties (Fig. 6a), whereas the specimens from the sills show single to multidomain magnetite (Fig. 6a), or pseudosingle to multidomain pyrrhotite properties (Fig. 6b).

Orthogonal step demagnetization plots (Zijderveld, 1967) show the change in direction (declination and inclination) of a specimen's remanence with its intensity expressed as a ratio of its NRM intensity as it is demagnetized. Representative plots for specimens from the pluton generally trend towards the origin (Fig. 7a-d) with a steeply-down inclination and a north-to-east declination. Any viscous or secondary magnetization is readily removed by 20 mT (Fig. 7a, b) or 200°C (Fig. 7c, d). The vector plots for specimens from the sills also trend towards the origin, however, they do not show any viscous component (Fig. 7e, f). The sills have directions either moderately upward (Fig. 7e) or steeply down (Fig. 7f).

The specimen ChRM directions for each site are averaged to obtain the site average, and this was successfully accomplished for 12 of the 13 sites from within the pluton (Table 2; Fig. 8). The specimen ChRM directions for site 07 were randomly oriented so that a site mean could not be calculated. The site mean directions for sites 02 and 06 in the pluton are not included in the unit mean ChRM direction because they are significantly different at the 95% confidence level from the average of the other 10 granitic sites. The granitic sites yield an average unit mean ChRM direction of declination (D) = 4.1°, inclination (I) = 73.0°, radius of the cone of 95% confidence (α_{95}) = 9.5°, precision parameter (k) = 27, and number of sites (N) = 10. Site mean ChRM directions were successfully calculated for all six sill sites (Table 2; Fig. 8). The ChRM direction from sill site 10 is significantly different at the 95% confidence level from the average of the other five sill sites and, therefore, is not used in the calculation of the unit mean direction. The unit mean direction for the sills is at D = 26.5°, I = 86.9°, α_{95} = 21.0°, k = 15 and N = 5. Combining the 15 sites yields a unit mean direction at D = 5.9°, I = 77.7°, α_{95} = 8.8° and k = 20.

The site mean directions of both the pluton and the sills can be statistically combined with confidence because the two have been shown to be related mineralogically, and to be coeval, thus their magnetizations should have been acquired during a similar time interval. Further, the mean direction of the sites from the pluton is not significantly different than the mean direction of the sites from the sills (Table 2). This similarity is further supported by the results of the F-statistic test (McFadden and Lowes, 1981) which is used to determine if two sample populations of directions can be drawn from one population of directions. The calculated F-statistic (F_{calc} = 2.07) is less than the tabulated value (F_{tab} = 3.81), therefore, the mean ChRM directions for the pluton and for the sills may be assumed to be from the same population (McFadden and Lowes, 1981). This suggests that the sills have not endured any post-intrusion tilting, thus indicating that they were intruded into already tilted strata.

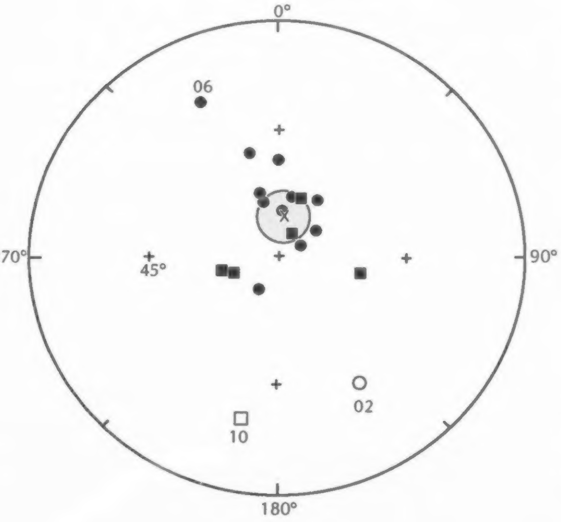


Figure 8. *Equal-area stereonet showing the site mean ChRM directions for the Teslin Crossing Pluton and sills from Table 2. Circles are sites in the central phase and squares are sites from the sills. The unit mean ChRM direction is shown by the "X" with its cone of 95% confidence. Closed (open) symbols represent directions in the lower (upper) hemisphere of the net. Numbers refer to sites that are discussed in the text.*

Table 2. *Site-averaged paleomagnetic data for the Teslin Crossing Pluton. N, n is the number of specimens measured and the number of specimens used in the site average. The mean direction is given by its declination (Dec), inclination (Inc), radius of cone of 95% confidence (α_{95}), and precision parameter (k; Fisher, 1953). Mean* – number of sites used in mean direction for the pluton or the sills.*

Site	N, n	Dec (°)	Inc (°)	α_{95} (°)	k
Granitoids					
01	9, 6	54.1	74.8	12.9	28
02	7, 4	147.2	-35.7	24.3	15
03	12, 12	4.8	74.5	9.7	21
04	12, 12	34.8	67.1	7.7	33
05	7, 7	12.5	69.4	7.9	60
06	7, 6	333.7	26.5	6.0	125
07	8, 0	——	——	——	——
14	10, 10	344.2	67.7	6.2	61
15		61.1	81.8	8.4	45
16	8, 8	345.4	71.1	5.4	92
17	9, 9	211.6	78.0	16.2	18
18	7, 6	0.2	55.8	7.1	39
19	12, 12	344.8	52.1	6.2	50
Mean*	**13, 10**	**4.1**	**73.0**	**9.5**	**27**
Sills					
08	12, 10	29.8	81.0	20.9	6
09	10, 6	100.7	62.1	24.1	9
10	13, 11	192.9	-29.5	9.3	25
11	14, 14	257.1	71.8	3.1	163
12	9, 8	20.9	69.3	8.7	41
13	23, 23	251.3	74.9	7.6	17
Mean*	**6, 5**	**26.5**	**86.9**	**21.0**	**15**

DISCUSSION

The Teslin Crossing Pluton is considered to postdate regional deformation because its host rocks are largely flat-lying. Also, deformation of most rocks in the Stikine Terrane occurred during the Early to Middle Jurassic, and subsequent disturbances were localized and largely limited to strike-slip and normal faulting (Hart and Radloff, 1990). Further, the pluton shows only minor alteration in its petrography, an observation that is supported by its low LOI values (Hart, 1996). Thus the reported K-Ar ages, the measured crystallization temperatures, and the ChRM directions, are all considered primary.

The unit mean ChRM direction is used to calculate the paleopole for the Teslin Crossing Pluton. The paleopole gives the location of the magnetic pole at the time of intrusion. The paleopole can then be compared to a reference paleopole of similar age from the North American craton to determine if there has been any relative tectonic motion between the host Stikine Terrane and the craton since Jurassic intrusion. The calculated paleopole for the pluton and sills is located at 110.6°W, and 84.3°N (dp = 16°, dm = 17°; radii of oval of 95% confidence) with respect to the fixed-position North American craton. The paleopole is compared with the interpolated 177 Ma reference pole from Besse and Courtillot (1991) at 102.5°E, 67.5°N ($\alpha_{95} = 2.9°$; Fig. 9). The comparison suggests that the pluton, along with the Stikine Terrane, has been translated away from the reference pole or southwards by 21.1° ± 7.4° (2320 ± 810 km) and rotated clockwise by 33° ± 18° with respect to the craton since 177 Ma.

If the Teslin Crossing Pluton is carrying a primary remanence, then the geographic location of the pluton at 177 Ma can be estimated by determining the great-circle distance. This great-circle distance, or the paleocolatitude, provides only an estimate of paleolatitude because paleolongitude cannot be constrained. With respect to the reference pole, the tectonic estimate for the Teslin Crossing Pluton positions the Stikine Terrane either along the present-day margin of western Alaska or across the Pacific Basin along the eastern margin of present-day Kamchatka or Asia (Fig. 9). Noting that the North American craton was at a subtropical paleolatitude ~35° south of present-day latitudes at ~177 Ma (Engebretson et al., 1985), this also places the Stikine Terrane in a subtropical paleolatitude, thereby explaining the paleoclimate indicators such as warm water carbonates and fauna in the Jurassic host rocks (Carter et al., 1991).

Statistically, the translation estimate for the pluton is insignificantly different from that of the tilt-corrected estimate for the 172 Ma Fourth of July Batholith that is located in northern British Columbia in the Cache Creek Terrane (Fig. 1; Table 3). The fact that these two intrusions yield similar tectonic estimates suggests that the Stikine and Cache Creek Terranes were likely proximal to each other during and following the Jurassic until final accretion to the North American craton.

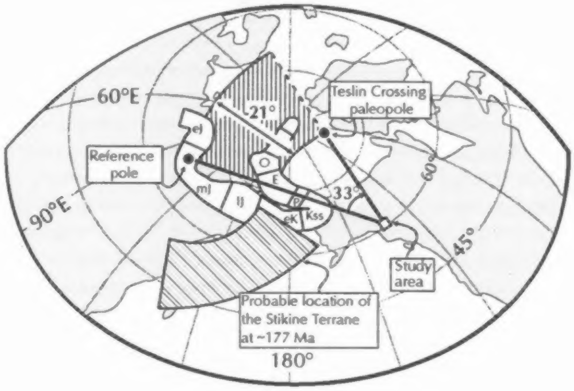

60°E
21°
Teslin Crossing paleopole
eJ
Reference pole
O
E
mJ
lJ
33°
P
eK
Kss
60°
90°E
45°
Study area
Probable location of the Stikine Terrane at ~177 Ma
180°

Figure 9. *Location of the Teslin Crossing study area, its paleopole, the interpolated 177 Ma reference pole and the apparent polar wander path (relative to the North American craton) from Besse and Courtillot (1991). The approximate location of the Stikine Terrane at 177 Ma is the diagonally light-ruled area.*

There are two factors that support a trans-Pacific Basin motion for the two terranes. First, the Cache Creek Terrane contains Permian-aged Tethyan fossils which are correlated with coeval fossils found in eastern Asia, but which are not found elsewhere in other Cordilleran terranes or in North America (Carter et al., 1991). Thus, at least during the Late Paleozoic, the Cache Creek Terrane was to the west of, and distant from North American craton, because its fauna interacted with those of the Asian craton. Second, the Farallon oceanic plate which underlay the ancestral Pacific Basin from ~200 to 80 Ma had an easterly to southeasterly motion for most of the Jurassic and earliest Cretaceous period (Engebretson et al., 1985). Thus, there is a mechanism available to move the terranes across the basin to the North American craton.

Two previous paleomagnetic studies on rock units of Jurassic or older age in the Stikine and Cache Creek Terranes yielded inconclusive results. In the first, layered Paleozoic rocks of mafic volcanic and carbonate provenance in northern British Columbia yielded a ChRM component that proved to be a chemical remagnetization with an unknown acquisition age (Cole et al., 1992). The most conservative interpretation involved Early Jurassic remagnetization following folding and tilting, resulting in minimal tectonic motion, i.e., the resulting paleopole was located near the reference pole. The second study involved the 190 Ma Hazelton Group volcanic rocks in central British Columbia, and also yielded a paleopole similar to its reference pole, suggesting that there had been no tectonic motions (Monger and Irving, 1980; Vandall and Palmer, 1990).

However, it is noted that the Hazelton results are from six different localities and show ranges in both translation and rotation estimates (e.g., northward translations of 12° to -3°, clockwise rotations of -15° to 117°) which when averaged, resulted in no net translation. The variation in the estimates may be caused by alteration through metamorphism, incorrectly measuring and/or correcting for local bedding tilts, or insufficiently delineating the primary remanence because it was carried in both magnetite and hematite (Monger and Irving, 1980; Vandall and Palmer, 1990). This last cause is considered a problem because the formation of the hematite may be later than the extrusive event and thus may be masking the primary magnetite direction. It is suggested that the previous studies are suspect because of the variability of their estimates and the uncertainty about when magnetization was acquired.

Tectonic estimates for the Teslin Crossing Pluton are compared with the previously reported estimates from the Yukon (Table 3). The ~112 Ma Whitehorse Batholith yielded a translation estimate of ~11° poleward or northward, and a clockwise rotation of ~60° (Harris et al., 1997). The 109 Ma Mount McIntyre Pluton yielded two clusters of site mean ChRM directions, but only the northeast (NE) cluster gave geologically reasonable results, suggesting a northward translation of ~14° and clockwise rotation of ~80° (Table 3; Harris et al., 1996).

Results from the 75 Ma Mount Lorne Stock indicate a northward translation of 10.5° and a clockwise rotation of ~60° (Harris et al., in press). The 70 Ma Carmacks Group volcanic unit yielded estimates of 17° northward translation and 20° of clockwise rotation (Johnston et al., 1996; Wynne et al., 1998). This estimate is not consistent with the other estimates and is considered tenuous (Butler, 1990; Harris et al., 1996, 1997, in press).

Except for the Carmacks estimate, the Cretaceous data for the Yukon are in agreement with other data in the Stikine Terrane from central and southern British Columbia (i.e., Monger and Irving, 1980; Symons and Litalien, 1984; Irving and Thorkelson, 1990; Irving et al., 1996). They support the proposed model in which the Stikine Terrane has had ~1100 to 1500 km of northward translation since mid-Cretaceous time (Irving and Wynne, 1991; Harris et al., 1997; Harris, 1998, and references therein). An even greater northward displacement of ~2300 km is suggested by the Early Cretaceous Endako Intrusions from central British Columbia since 142 Ma relative to the craton (Symons, 1973; Symons, 1983; Harris, 1998). It is now suggested, through the Jurassic data from the Teslin Crossing Pluton and similar results from the coeval Fourth of July Batholith, that prior to the Early Cretaceous, the Stikine and Cache Creek Terranes were located in the Pacific Basin away

Table 3. *Summary of paleopoles and tectonic estimates relative to the fixed position North American reference pole (Besse and Courtillot, 1991) for selected igneous units in the northern Canadian Cordillera. CW - clockwise; CCW - counterclockwise; Comb - combined mean direction; Tilt-cor - tilt-corrected mean direction. References for the collections are (1) Johnston et al. (1996), Wynne et al. (1998); (2) Harris et al. (in press); (3) Harris et al. (1996); (4) Harris et al. (1997); (5) Symons (1983), Harris (1998); (6) Harris (1998).*

Collection	Age (Ma)		Paleopole, d_p, d_m	Translation	Rotation
Carmacks Group Volcanics[1]	70		88.6°E, 78.4°N 7.1°, 8.4°	17.0° ± 6.5°	20° ± 10° CW 1870 ± 720 km
Mount Lorne[2]	75		69.1°W, 78.3°N 4.1°, 4.5°	10.5° ± 3.5°	57° ± 11° CW 1170 ± 390 km
Mount McIntyre[3]	109	NE	119.6°W, 70.5°N 5.5°, 6.1°	14.3° ± 5.0°	79° ± 16° CW 1590 ± 550 km
		NW	111.1°E, 57.9°N 7.6°, 10.2°	34.8° ± 6.9°	1° ± 17° CW 3870 ± 770 km
		Comb	79.4°E, 86.8° 12.0°, 13.5°	22.1° ± 7.4°	27° ± 18° CW 2450 ± 820 km
Whitehorse[4]	~112		105.5°W, 81.7°N 5.3°, 5.7°	11.0° ± 4.8°	59° ± 17° CW 1220 ± 530 km
Endako[5]	~142		121.8°E, 58.4°N 8 5°, 12.1°	20.5° ± 10°	1.9° ± 15° CCW 2270 ± 1100 km
Fourth of July[6]	172	In situ	59.8°W, 65.4°N 5.7°, 6.4°	-11.8° ± 4.0°	78° ± 7° CW -1310 ± 450 km
		Tilt-cor	80.6°W, 54.8°N 6.0°, 6.6°	-16.0 ± 4.0°	106° ± 7° CW -1770 ± 450 km
Teslin Crossing	177		110.3°W, 84.3°N 15.5°, 16.5°	-21.0° ± 7.4°	33° ± 18° CW -2340 ± 820 km

from the North American craton, and were carried eastward by the Farallon Plate through the Jurassic and Early Cretaceous time.

In conclusion, the northern Stikine Terrane was likely situated across the Pacific Basin during the Middle Jurassic, when it was intruded by the Teslin Crossing Pluton at ~177 Ma. The northern Stikine Terrane was also likely loosely-amalgamated with the Cache Creek Terrane at this time and the two were transported easterly to southeasterly by the Farallon oceanic plate across the Pacific Basin until mid-Cretaceous time. At this time, fracturing of the Pacific Plate caused the Stikine and Cache Creek Terranes to move northward and slightly oblique into the North American craton on the Kula plate until northward translation ended around 50 Ma (e.g., Bardoux and Irving, 1989; Symons and Wellings, 1989; Vandall and Palmer, 1990; Kelley, 1993; Harris et al., 1998). This two-stage tectonic translation satisfies the known paleomagnetic constraints on the Stikine and Cache Creek Terranes in Jurassic through early Tertiary time.

ACKNOWLEDGEMENTS

The authors wish to thank Dr. Yves Thibault with the microprobe analyses; Charlie Roots for insightful reviews; and, NSERC for funding through the LITHOPROBE - SNORCLE project. This is LITHOPROBE contribution #981.

REFERENCES

Ague, J.J. and Brandon, M.T., 1992. Tilt and northward offset of Cordilleran batholiths resolved using igneous barometry. Nature, vol. 360, p. 146-149.

Ague, J.J. and Brandon, M.T., 1996. Regional tilt of the Mount Stuart batholith, Washington, determined using aluminum-in-hornblende barometry: Implications for northward translation of Baja British Columbia. Geological Society of America, Bulletin, vol. 108, p. 471-488.

Bardoux, M. and Irving, E., 1989. Paleomagnetism of Eocene rocks of the Kelowna and Castlegear areas, British Columbia: Studies in determining paleohorizontal. Canadian Journal of Earth Sciences, vol. 26, p. 829-844.

Besse, J. and Courtillot, V., 1991. Revised and synthetic apparent polar wander paths of the African, Eurasian, North American and Indian plates, and true polar wander since 200 Ma. Journal of Geophysical Research, vol. 96, p. 4029-4050.

Butler, R.F., 1990. Northward motion of the Whitehorse Trough: Paleomagnetic evidence from the Upper Cretaceous Carmacks Group: Discussion. Canadian Journal of Earth Sciences, vol. 27, p. 614-617.

Carter, E.S., Orchard, M.J., Ross, C.A., Ross, J.R.P., Smith, P.L. and Tipper, H.W., 1991. Part B. Paleontological signatures of terranes. *In:* Chapter 2 of Geology of the Cordilleran Orogen in Canada, H. Gabrielse and C.J. Yorath (eds.). Geological Survey of Canada, Geology of Canada, no. 4, p. 28-38.

Cole, F., Butler, R.F. and Gehrels, G.E., 1992. Paleomagnetism of late Paleozoic rocks in the northern Cache Creek Terrane near Atlin, British Columbia. Canadian Journal of Earth Sciences,
vol. 29, p. 486-498.

Cook, F. and Erdmer, P. (eds.), 1995. Slave-Northern Cordillera Lithospheric Evolution (SNORCLE) Transect and Cordilleran Tectonics Workshop Meeting. University of Calgary, Calgary, Alberta, Lithoprobe Report No. 44, 97 p.

Cook, F. and Erdmer, P. (eds.), 1996. Slave-Northern Cordillera Lithospheric Evolution (SNORCLE) Transect and Cordilleran Tectonics Workshop Meeting. University of Calgary, Calgary, Alberta, Lithoprobe Report No. 50, 226 p.

Engebretson, D.C., Cox, A. and Gordon, R., 1985. Relative motions between oceanic and continental plates in the Pacific Basin. Geological Society of America, Special Paper 206, 59 p.

Essene, E.J., 1989. The current status of thermobarometry in metamorphic rocks. *In:* J.S. Daly, R.A. Cliff and Yardley, B.W.D. (eds.), Evolution of Metamorphic Belts. Blackwell Scientific Publications, Oxford, p. 1-44.

Fisher, R.A., 1953. Dispersion on a sphere. Proceedings of the Royal Society of London, vol. A217, p. 295-305.

Guidotti, C.V., 1984. Micas in metamorphic rocks. Reviews in Mineralogy, vol. 13, p. 357-468.

Guidotti, C.V., Cheney, J.T. and Guggenheim, S., 1977. Distribution of titanium between co-existing muscovite and biotite in pelitic schists from northwestern Maine. American Mineralogist, vol. 62, p. 438-448.

Harris, M.J., 1998. Geotectonic motions of northern Cordilleran terranes from paleomagnetic measurements with geothermobarometric corrections. Unpublished Ph. D. thesis, University of Western Ontario, London, Ontario, 205 p.

Harris, M.J., Symons, D.T.A., Blackburn, W.H. and Hart, C.J.R., 1996. Paleomagnetic study of the Mount McIntyre pluton, Whitehorse map area (105D), southern Yukon Territory. *In:* Yukon Exploration and Geology 1996, Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada,
p. 122-130.

Harris, M.J., Symons, D.T.A., Blackburn, W.H. and Hart, C.J.R., 1997. Paleomagnetic and geobarometric study of the mid

Cretaceous Whitehorse pluton, Yukon Territory. Canadian Journal of Earth Sciences, vol. 34, p. 1379-1391.

Harris, M.J., Symons, D.T.A., Blackburn, W.H. and Hart, C.J.R., in press. Paleomagnetic and geobarometric study of the Late Cretaceous Mount Lorne Pluton, southern Yukon Territory. Canadian Journal of Earth Sciences, submitted.

Harris, M.J., Symons, D.T.A., Hart, C.J.R. and Blackburn, W.H., 1998. An early Eocene end for northward displacement of the Coast Plutonic Complex in northern Canada and Alaska from paleomagnetism. Geological Association of Canada, Annual General Meeting, Abstract with Program vol. 23, Quebec City, A-73.

Hart, C.J.R., 1996. Geology and geochemistry of the Teslin Crossing Pluton: A gold-rich alkalic porphyry target. *In:* Yukon Exploration and Geology 1996, Exploration and Geological Services, Yukon, Indian and Northern Affairs Canada, p. 131-137.

Hart, C.J.R., 1997. A transect across northern Stikinia: Geology of the northern Whitehorse map area (105D 13-16), southern Yukon Territory. Exploration and Geological Services, Yukon, Indian and Northern Affairs Canada, Bulletin 8, 101 p.

Hart, C.J.R. and Radloff, J.K., 1990. Geology of Whitehorse, Alligator Lake, Fenwick Creek, Carcross and part of Robinson map areas (105D/11, 6, 3, 2 and 7). Exploration and Geological Services, Yukon, Indian and Northern Affairs Canada, Open File 1990-4.

Irving, E. and Thorkelson, D.J., 1990. On determining paleohorizontal and latitudinal shifts: Paleomagnetism of Spences Bridge Group, British Columbia. Journal of Geophysical Research, vol. 95, p. 19213-19234.

Irving, E. and Wynne, P.J., 1991. Paleomagnetism: review and tectonic implications, Chapter 3. *In:* Geology of the Cordilleran Orogen in Canada, H. Gabrielse and C.J. Yorath (eds.), Geological Survey of Canada, Geology of Canada, no. 4, p. 61-86.

Irving, E., Wynne, P.J., Thorkelson, D.J. and Schiarizza, P., 1996. Large (1000 to 4000 km) northward movements of tectonic domains in the northern Cordillera, 83 to 45 Ma. Journal of Geophysical Research, vol. 101, p. 17901-17916.

Johnston, S.T., Wynne, P.J., Francis, D., Hart, C.J.R., Enkin, R.J. and Engebretson, D.C., 1996. Yellowstone in Yukon: The Late Cretaceous Carmacks Group. Geology, vol. 24, p. 997-1000.

Kelley, K., 1993. Relative motions between North America and oceanic plates of the Pacific basin during the past 130 million years. Unpublished M.Sc. thesis, Western Washington University, Bellingham, Washington, USA.

LeBel, L., 1979. Micas magmatiques et hydrothermaux dans l'environnement du porphyre cuprifère de Cerro Verde-Santa Rosa, Pérou. Bulletin de Mineralogie, vol. 102, p. 35-41.

McFadden, P.L. and Lowes, F.J., 1981. The discrimination of mean directions drawn from Fisher distributions. Geophysical Journal of the Royal Astronomical Society, vol. 67, p. 19-33.

Monger, J.W.H. and Irving, E., 1980. Northward displacement of north-central British Columbia. Nature, vol. 285, p. 289-294.

Pangman, P.G. and VanTassell, R.E., 1972. Geological and geochemical report on the TUV 1 to 24 mineral claims, Miller Creek area. Mineral Resources Directorate, Yukon, Indian and Northern Affairs Canada, Yukon Assessment Report 060152, 10 p.

Stevens, R.D., Delabio, R.N. and Lachance, G.R., 1982. Age determinations and geological studies. Geological Survey of Canada, Paper 82-2, 56 p.

Symons, D.T.A., 1973. Paleomagnetic results from the Jurassic Topley Intrusions near Endako, British Columbia. Canadian Journal of Earth Sciences, vol. 10, p. 1099-1108.

Symons, D.T.A., 1983. Further paleomagnetic results from the Jurassic Topley intrusions in the Stikinia subterrane of British Columbia. Geophysical Research Letters, vol. 10, p. 1065-1068.

Symons, D.T.A. and Litalien, C.R., 1984. Paleomagnetism of the Lower Jurassic Copper Mountain Intrusions and the geotectonics of Terrane I, British Columbia. Geophysical Research Letters, vol. 11, p. 685-688.

Symons, D.T.A. and Wellings, M.R., 1989. Paleomagnetism of the Eocene Kamloops Group and the cratonization of Terrane I of the Canadian Cordillera. Canadian Journal of Earth Sciences, vol. 26, p. 821-828.

Tempelman-Kluit, D.J., 1984. Geology map of Laberge (105E) and Carmacks (115I) map areas, Yukon. Geological Survey of Canada, Open File 1101, (two 1:250 000 scale maps and legend).

Vandall, T.A. and Palmer, H.C., 1990. Canadian Cordilleran displacement: palaeomagnetic results from the Early Jurassic Hazelton Group, Terrane I, British Columbia, Canada. Geophysical Journal International, vol. 103, p. 609-619.

Wheeler, J.O. and McFeely, P., 1991. Tectonic assemblage map of the Canadian Cordillera and adjacent parts of the United States of America. Geological Survey of Canada, Map 1712A, 1:2 000 000 scale.

Wynne, P.J., Enkin, R.J., Baker, J., Johnston, S.T. and Hart, C.J.R., 1998. The big flush: paleomagnetic signature of a 70 Ma regional hydrothermal event in displaced rocks of the northern Canadian Cordillera. Canadian Journal of Earth Sciences, vol. 35, p. 657-671.

Zijderveld, J.D.A., 1967. A.C. demagnetization of rocks: analysis of results. *In:* Methods in Paleomagnetism, D.E.W. Collision, K.K. Crier, and S.K. Runcorn (eds.), Elsevier, Amsterdam, The Netherlands, p. 254-286.

Preliminary results from water sampling in the Pelly-Cassiar Platform volcanic belt, southeastern Yukon

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Hunt, J.A. 1999. Preliminary results from water sampling in the Pelly-Cassiar Platform volcanic belt, southeastern Yukon. *In:* Yukon Exploration and Geology 1998, C.F. Roots and D.S. Emond (eds.), Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 167-177.

ABSTRACT

Water and sediment samples were collected from 13 creeks/springs which drain the Devono-Mississippian Pelly Mountains volcanic belt that hosts the Wolf and MM volcanogenic massive sulphide (VMS) deposits. Preliminary results indicate that water and sediment sampling may be a viable method of exploration for VMS mineralization in this area. A creek draining the Wolf zinc-lead-silver deposit has elevated levels of lead and zinc in water and sediment samples. A sediment sample from the MM zinc-lead-copper deposit drainage is elevated in silver, copper and lead, but not zinc. A creek draining the Fire (Chzerpnough) prospect has elevated levels of barium, lead and zinc in sediment and cadmium, nickel and zinc in water.

Each creek sampled has a distinctive white precipitate, coating the rocks, sediment and vegetation in the creek bed, that is likely composed of aluminium hydroxide or aluminium and calcium sulphate.

RÉSUMÉ

Des échantillons d'eau et de sédiments ont été recueillis dans 13 ruisseaux et sources drainant la bande volcanique dévono-mississippienne des monts Pelly qui abrite les gisements de sufures massifs volcanogènes (SMV) Wolf et MM. Les résultats préliminaires indiquent que l'échantillonnage de l'eau et des sédiments peut s'avérer une méthode viable d'exploration des minéralisations de SMV dans cette région. Les échantillons d'eau et de sédiments d'un ruisseau drainant le gisement Wolf de zinc-plomb-argent présentent des concentrations élevées de Pb et de Zn. Un échantillon de sédiments du bassin versant du gisement MM de zinc-plomb-cuivre présente des concentrations élevées d'Ag, de Cu et de Pb, mais non de Zn. À l'emplacement d'un ruisseau drainant la zone d'intérêt Fire (Chzerpnough), les sédiments présentent des concentrations élevées de Ba, Pb et Zn et l'eau des concentrations élevées de Cd, de Ni et de Zn.

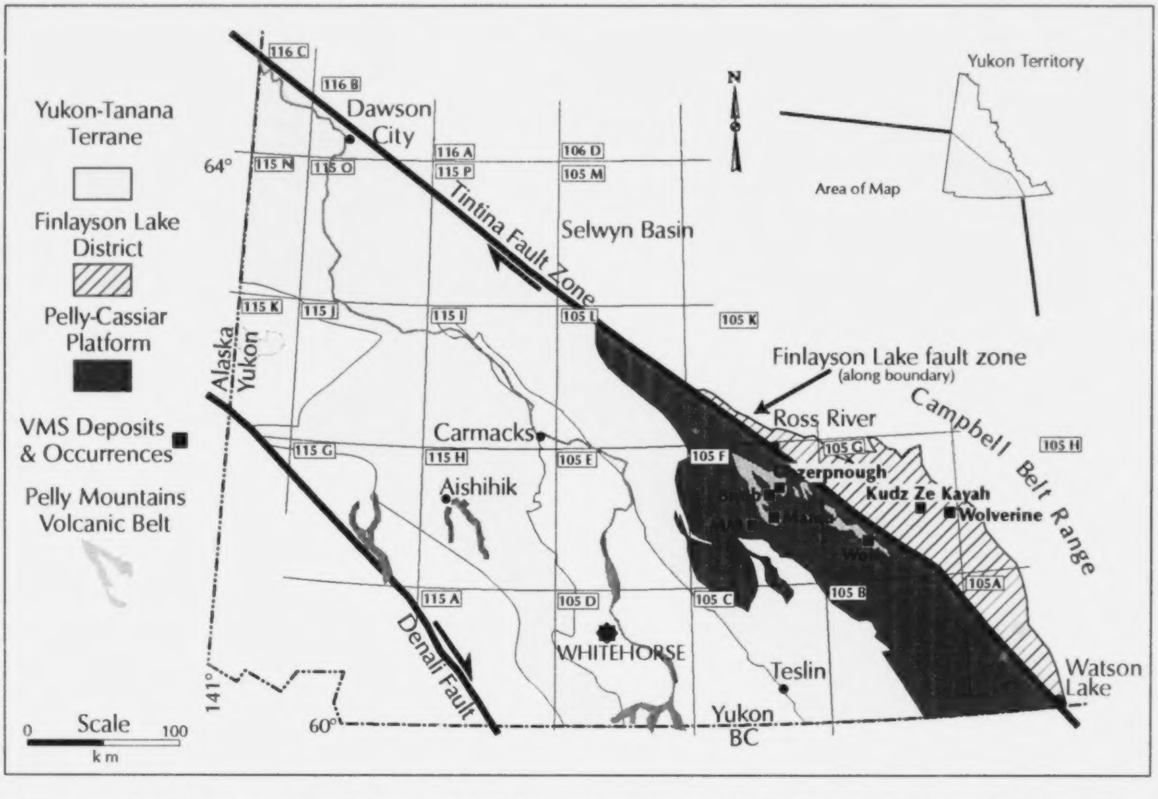
Chaque ruisseau échantillonné est charactérisé par un précipité blanc qui enrobe les roches, les sédiments et la végétation du lit des ruisseaux et qui est vraisemblablement composé d'hydroxyde d'aluminium ou d'aluminium et de sulfate de calcium.

INTRODUCTION

Volcanogenic massive sulphide (VMS) mineralization in the Pelly-Cassiar Platform is hosted by the Devono-Mississippian Pelly Mountains volcanic belt which is about 80 km long and up to 25 km wide (Fig. 1). The beds of creeks and springs draining the volcanic rocks are locally coated by a distinctive white precipitate several metres below the water source. This paper presents preliminary geochemical data from an orientation survey in which water and sediment samples were collected in 13 of these creeks (Fig. 2).

Previous studies have shown that groundwater and sediment chemistry can be a valuable guide to the discovery of concealed metal sulphides. For example, Lett and Jackaman (1995) and Lett et al. (1997) identified geochemical pathfinders in stream sediments and waters for base metal sulphide mineralization in the Kechika Trough of northeastern B.C. Earle (1975) showed that in some locations in the MacMillan Pass area of eastern Yukon, stream waters are a better guide to mineralization than stream sediment samples. This is especially true in acidic waters where the absorption of trace metals by secondary iron oxides in stream sediments is suppressed. Cameron (1977) reported that waters are the most convenient medium for more detailed levels of exploration in areas around massive sulphide mineralization hosted by Archean metavolcanic rocks in the Agricola Lake area, NWT. Using geochemical data for drill hole and spring water samples collected around the Eustice massive sulphide deposit in Quebec, Hoag and Webber (1976) determined that sulphate levels below 160 ppm were principally due to non-bacterial oxidation, whereas higher sulphate levels reflected extensive bacterial surface oxidation of sulphides. Sibbick (1995) analyzed sulphate and pH values from regional geochemical survey (RGS) data to identify areas with acidic high-sulphate streams. This analysis was carried out in an attempt to predict the location of areas with potential acid rock drainage (ARD) problems in the Mount Waddington area (NTS 92N) of British Columbia. In this area acid sulphate streams are associated with known mineralization.

In the present study, samples were collected to investigate the relationship between spring-water chemistry, type of precipitate, sediment chemistry and proximity to known mineralization. These data provide information on the use of water and sediment sampling in the search for VMS mineralization in the Pelly Mountains volcanic belt.


Yukon-Tanana Terrane
Finlayson Lake District
Pelly-Cassiar Platform
VMS Deposits & Occurrences ■
Pelly Mountains Volcanic Belt
Scale
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km
Yukon Territory
Area of Map
N
Dawson City
Selwyn Basin
Tintina Fault Zone
Finlayson Lake fault zone
(along boundary)
Ross River
Campbell Belt Range
Kudz Ze Kayah
Wolverine
Carmacks
Aishihik
WHITEHORSE
Teslin
Watson Lake
Denali Fault
Alaska
Yukon
Yukon
BC
64°
60°
141°
116 C
116 B
116 A
106 D
115 N
115 O
115 P
105 M
115 K
115 J
115 I
105 L
105 K
115 G
115 H
105 E
105 F
105 G
105 H
115 A
105 D
105 C
105 B
105A

Figure 1. *Location map of Pelly-Cassiar Platform and the Pelly Mountains volcanic belt (Modified after Wheeler and McFeely, 1991).*

DESCRIPTION OF STUDY AREA

LOCATION AND TOPOGRAPHY

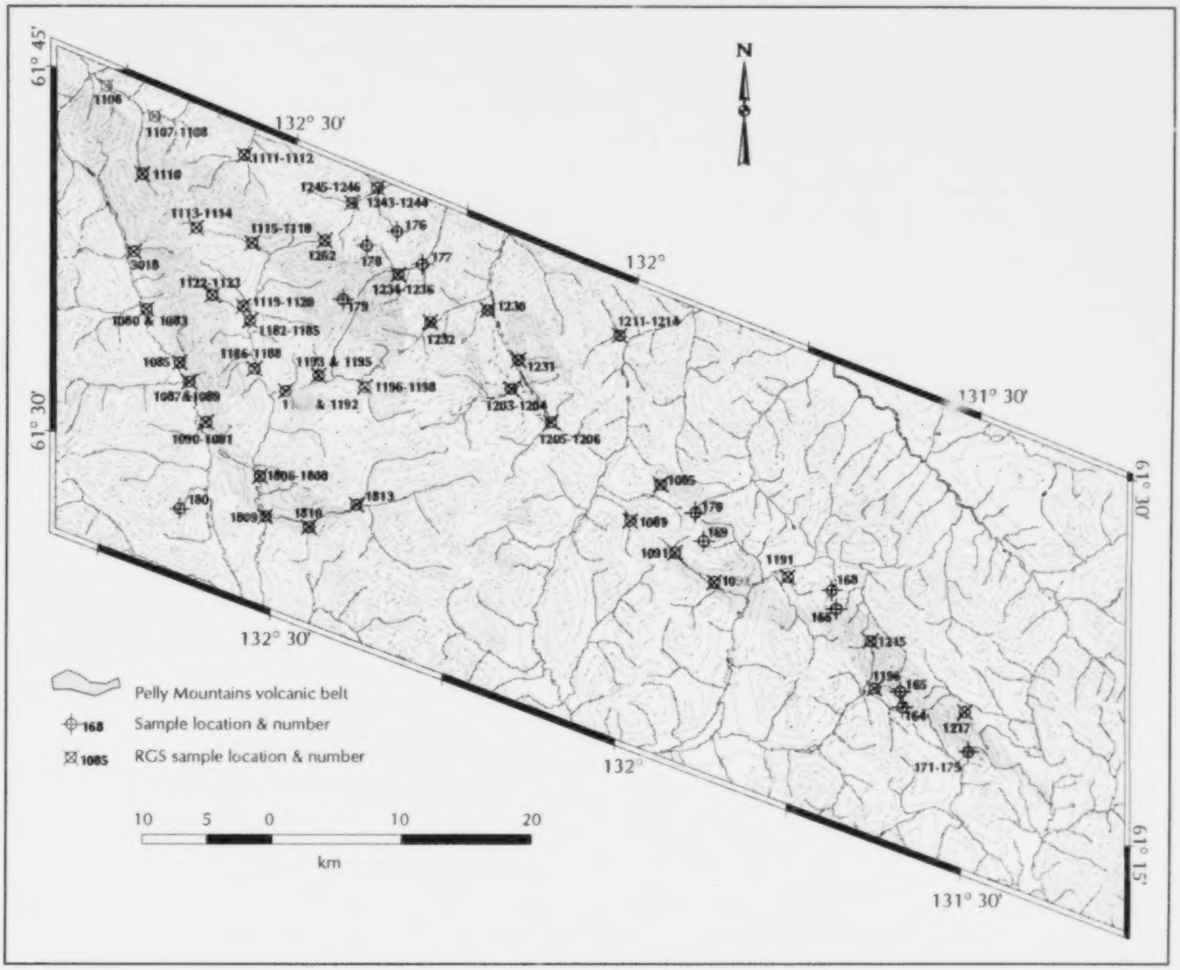
The region sampled lies within the Pelly-Cassiar Platform and forms part of the Pelly Mountains, which are characterized by northwest-southeast trending ridges from approximately 1,200 to 2,000 m in elevation. Evidence of glacial erosion and alpine glaciation occurs throughout the area. The tree line reaches up to roughly 1,600 m; above this elevation, ridge crests and steep slopes are covered by rocks, talus and felsenmeer.

The streams that were sampled have narrow stream beds, typically less than 1 m wide, with moderate gradients. Flow rates are seasonably variable but generally moderate.

GEOLOGICAL SETTING

Geology, mineralization and structure of the Pelly Mountains volcanic belt have been described by previous workers, including Wheeler et al. (1960a, b), Tempelman-Kluit et al. (1975 and 1976), Tempelman-Kluit (1977a, b), Morin (1977), Gordey (1977, 1981) and Mortensen (1979 and 1982); current geological mapping of the area can be found in Hunt (this volume). Principal geological elements of the volcanic belt can be summarized as follows:

- The belt trends roughly northwest-southeast and is made up of Devono-Mississippian intermediate to felsic volcanic rocks that conformably to unconformably overlie Silurian-Devonian carbonate and argillite;
- Similar Silurian-Devonian carbonate and argillite locally overlie the volcanic rocks along thrust faults;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176
3018
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177
1122-1133
1234-1236
1119-1120
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1080 & 1083
1182-1185
1232
1211-1214
1186-1188
1193 & 1195
1231
1085
1196-1198
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1191
168
166
1215
1196
165
164
1217
171-175
Pelly Mountains volcanic belt
168
Sample location & number
1085
RGS sample location & number
10
5
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10
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km

Figure 2. *Location map of the Pelly Mountains volcanic belt with sample locations. RGS locations are from Hornbrook & Friske, 1985, 1988.*

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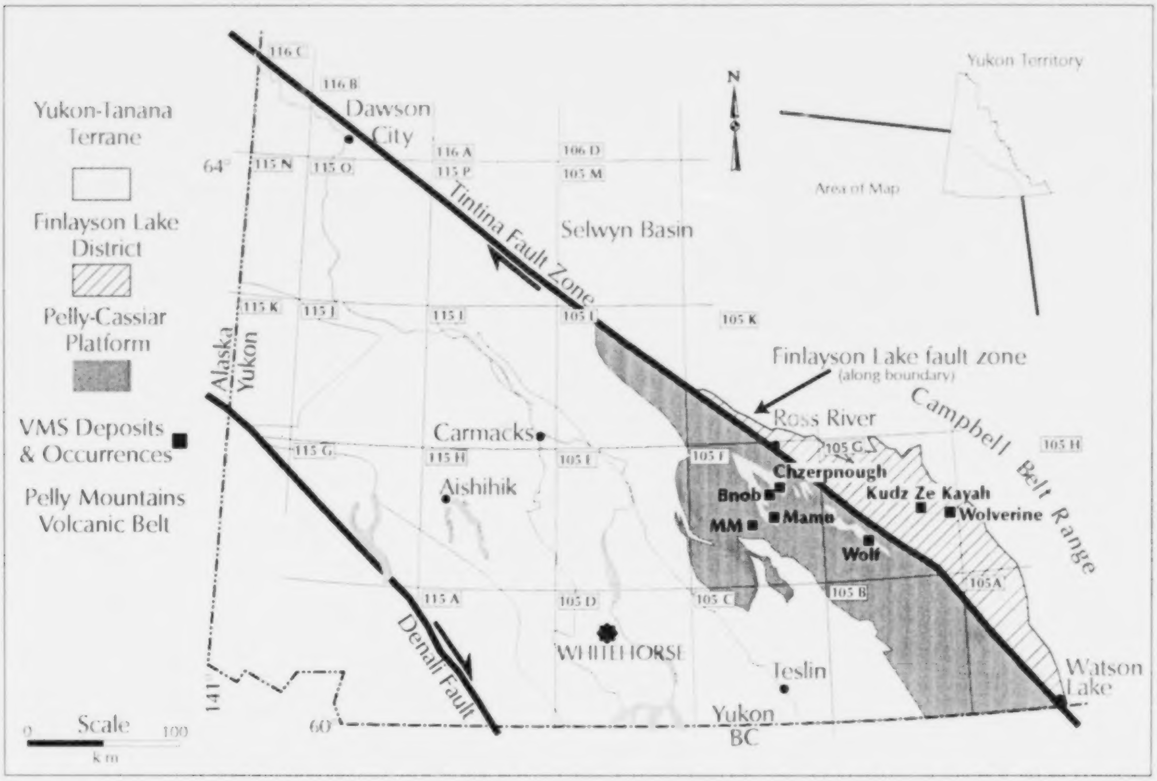
Yukon-Tanana Terrane
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VMS Deposits & Occurrences
Pelly Mountains Volcanic Belt
Scale
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km
116 C
116 B
Dawson City
64°
115 N
115 O
116 A
115 P
106 D
105 M
Tintina Fault Zone
Selwyn Basin
N
Yukon Territory
Area of Map
115 K
115 J
115 I
105 L
105 K
Alaska
Yukon
Finlayson Lake fault zone
(along boundary)
Ross River
Campbell Belt Range
115 G
115 H
Carmacks
105 E
105 F
105 G
105 H
Chzerpnough
Bnob
Kudz Ze Kayah
Wolverine
Aishihik
MM
Mamu
Wolf
115 A
105 D
105 C
105 B
105 A
Denali Fault
WHITEHORSE
Teslin
Watson Lake
141
60
Yukon
BC

Figure 1. Location map of Pelly-Cassiar Platform and the Pelly Mountains volcanic belt (Modified after Wheeler and McFeely, 1991).

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- The belt trends roughly northwest-southeast and is made up of Devono-Mississippian intermediate to felsic volcanic rocks that conformably to unconformably overlie Silurian-Devonian carbonate and argillite;
- Similar Silurian-Devonian carbonate and argillite locally overlie the volcanic rocks along thrust faults;

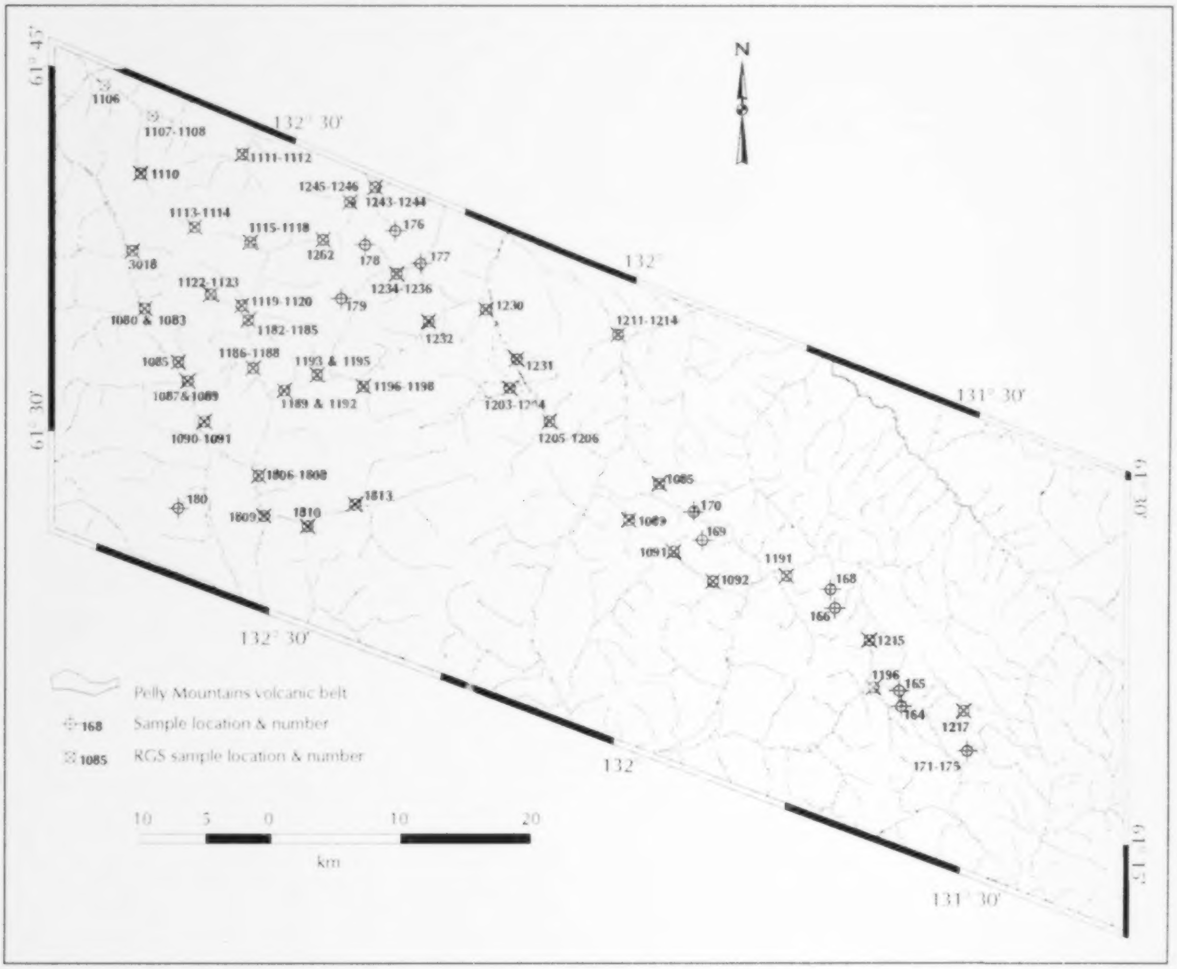
N
61° 45'
61° 30'
132° 30'
132°
131° 30'
61° 30'
61° 15'
132° 30'
132
131° 30'
1106
1107-1108
1111-1112
1110
1245-1246
1243-1244
1113-1114
1115-1118
176
3018
1262
178
177
1122-1123
1234-1236
1119-1120
179
1230
1080 & 1083
1182-1185
1232
1211-1214
1085
1186-1188
1193 & 1195
1231
1087&1089
1189 & 1192
1196-1198
1203-1204
1090-1091
1205-1206
1806-1808
1085
180
1809
1810
1813
1089
170
169
1091
1191
1092
168
166
1215
1196
165
164
1217
171-175
Pelly Mountains volcanic belt
168 Sample location & number
1085 RGS sample location & number
10
5
0
10
20
km

Figure 2. *Location map of the Pelly Mountains volcanic belt with sample locations. RGS locations are from Hornbrook & Friske, 1985, 1988.*

- The volcanic rocks are dominantly greenschist facies metamorphic grade and have undergone two, and locally three, phases of deformation;
- VMS mineralization including the Wolf (pyrite ± sphalerite ± galena ± barite) and MM (barite ± pyrite ± sphalerite ± galena ± chalcopyrite) deposits is hosted by felsic rocks within the volcanic succession (Yukon Minfile, 1997; Gibson et al., this volume).

SAMPLING AND FIELD METHODS

A total of 15 sites in the volcanic belt were sampled over a two-day period in late July, 1998. At each site, white precipitate coats the clastic sediment and vegetation in the creek bed. This precipitate is not generally found where the water surfaces, but is evident in the channel several metres downstream from the discharge point.

Sample sites are described in Appendix A and their location is shown in Figure 2 and Table 1. One water and one sediment sample were collected from each site with the exception of the spring draining the Wolf deposit (informally named Pearl creek) which was sampled in four locations, each an increased distance from the source as shown in Figure 3, and sites 167 and 174, where only sediment samples were collected.

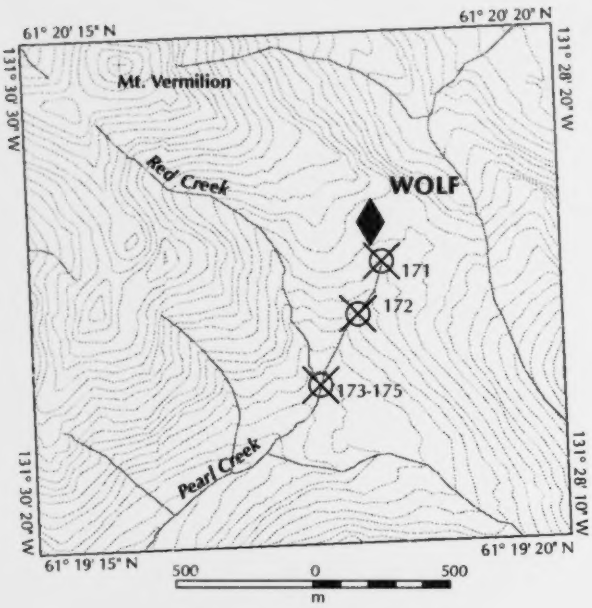

Figure 3. *Location of samples collected from Pearl Creek (Wolf deposit).*

The following samples and data were collected at each of the study sites:

- Water pH and conductivity (dissolved solids) were measured with Cole-Parmer hand-held metres.
- The temperature was measured using a scientific thermometer.
- Two one-litre bottles of water were taken from springs, surface streams or seepages. One of the bottles of water was acidified with ultrapure nitric acid to pH 2. Both bottles were filtered (flow through) using a 0.45 µm filter to give samples of 250 ml. The water samples that were acidified were done so before being filtered which may have altered the concentration of some elements in solution. Samples 170 (acidified) and 170a (non-acidified) show an example of the effects of acidification: the concentration of most elements, with the exception of As, B, Fe and K were increased. Therefore, the absolute values of elements in these samples should not be compared with those from other studies. However, since all samples were treated equally in this study they can be compared to one another.
- A one- to two-kg sample of sediment (including precipitate) in/beside the creek bed.

Four duplicate water samples were collected and one blank was added to give a total of 20 water samples. Two duplicates were collected for a total of 19 sediment samples.

LABORATORY ANALYSIS

Filtered, acidified water samples were analyzed for a suite of 33 elements (Ag, Al, As, B, Ba, Be, Bi, Ca, Cd, Ce, Co, Cr, Cu, Fe, K, Li, Mg, Mn, Mo, Na, Ni, P, Pb, S, Sb, Se, Si, Te, Ti, Tl, V, W & Zn) by inductively coupled plasma (ICP) emission spectroscopy at ACME Analytical, Vancouver, British Columbia. Four of the samples were also analyzed by inductively coupled plasma mass spectrometry (ICP-MS) at Activation Laboratories Ltd., Ancaster, Ontario, for a suite of 66 elements (Li, Na, Mg, Al, Si, K, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, Ge, As, Se, Br, Rb, Sr, Dy, Ho, Er, Tm, Yb, Lu, Hf, Ta, W, Re, Os, Pt, Au, Hg, Tl, Pb, Bi, Th, U, Y, Zr, Nb, Mo, Ru, Pd, Ag, Cd, In, Sn, Sb, Te, I, Cs, Ba, La, Ce, Pr, Nd, Sm, Eu, Gd & Tb) in order to compare analytical methods. Quality of the water geochemical data and possible sample contamination were monitored by analysis of filtered, distilled/deionized water blanks and blind sample replicates.

Non-acidified water samples were measured for sulphate content by ion chromatography at B.C. Research Ltd., Vancouver, British Columbia.

Stream sediment samples were analyzed by Chemex Labs Ltd. in North Vancouver, British Columbia. There the samples were dried and sieved to -80 mesh before being analyzed for 32 elements (Ag, Al, As, Ba, Be, Bi, Ca, Cd, Co, Cr, Cu, Fe, Ga, Hg, K, La, Mg, Mn, Mo, Na, Ni, P, Pb, Sb, Sc, Sr, Ti, Tl, U, V, W & Zn) by ICP-AES following aqua regia digestion.

RESULTS AND DISCUSSION

Results are shown in Table 1 for water samples analyzed by ICP. Several of the elements were excluded from the following interpretation because of probable significant loss during the interval between sampling and analysis (Hg) and absence of any detectable concentration in the samples (Ag, As, B, Be, Bi, Cr, Li, Sb, Se, Te, Tl, V & W). Table 2 contains the results for water samples analyzed by ICP-MS. Again several of the elements were excluded from the interpretation because of probable significant loss during the interval between sampling and analysis (Hg) and absence of any detectable concentration in the samples (Ta, W, Os, Pt, Au, Ru, Pd, Ag & Te).

The results for stream sediment samples are also shown in Table 1. The samples did not contain detectable concentrations of Bi, Ga, Hg, Na, Sb, Ti, Tl, U and W, and these elements were excluded from the interpretation.

CREEK PRECIPITATE

The composition of the distinct white precipitate which coats rocks, sediment and vegetation in some creeks draining the Pelly Mountains volcanic belt is unknown (samples of the precipitate have been sent for analysis but results are not yet available). However, it likely consists of aluminium hydroxide, or aluminium and calcium sulphates (K. Fletcher, pers. comm., 1998), or possibly barite. Changes in the water and sediment chemistry in Pearl Creek appear to support this interpretation as described below.

Table 1 and Figure 4 show that in Pearl Creek between the source (sample 171) and the beginning of the white precipitate (sample 172), the pH and temperature of the water increase while conductivity and the concentration of most elements in water decrease and those in the sediment increase; an exception to this is Pb which decreases in both sample mediums. The white precipitate probably occurs in response to the changes in pH and is likely composed primarily of Al, Ca and SO_4 minerals since the concentration of Al, Ca and SO_4 contained in the water decreases significantly and that of the sediment increases at the onset of precipitation (sample 172). Analysis of sample 172 using MINTEQ software predicted the following possible saturated minerals in Pearl Creek: $AlOHSO_4$, $Al_4(OH)_{10}SO_4$, alunite, boehmite, diaspore, ferrihydrite, gibbsite, goethite, hematite, K-jarosite, maghemite, cuprousferite and leidocrocite (Sibbick, 1998, written communication) suggesting that the white precipitate likely contains one or more of the above minerals.

A similar situation was described by Earle (1975) in the Nahanni map area (NTS 105 I) where a white aluminium hydroxide precipitate begins to form as the pH increases. Such precipitates may occur in any acidic environment and are likely the result of the weathering of sulphides. However, they are not necessarily an indication of mineralization as the acidity may be caused by finely disseminated sulphides throughout a rock unit and not by massive sulphide mineralization. For example, in the MacMillan Pass area, creeks with white precipitate are associated with the Howard's Pass deposit but also with barren areas underlain by black shale which contains fine grained disseminated pyrite (Earle, 1975; Goodfellow, 1989).

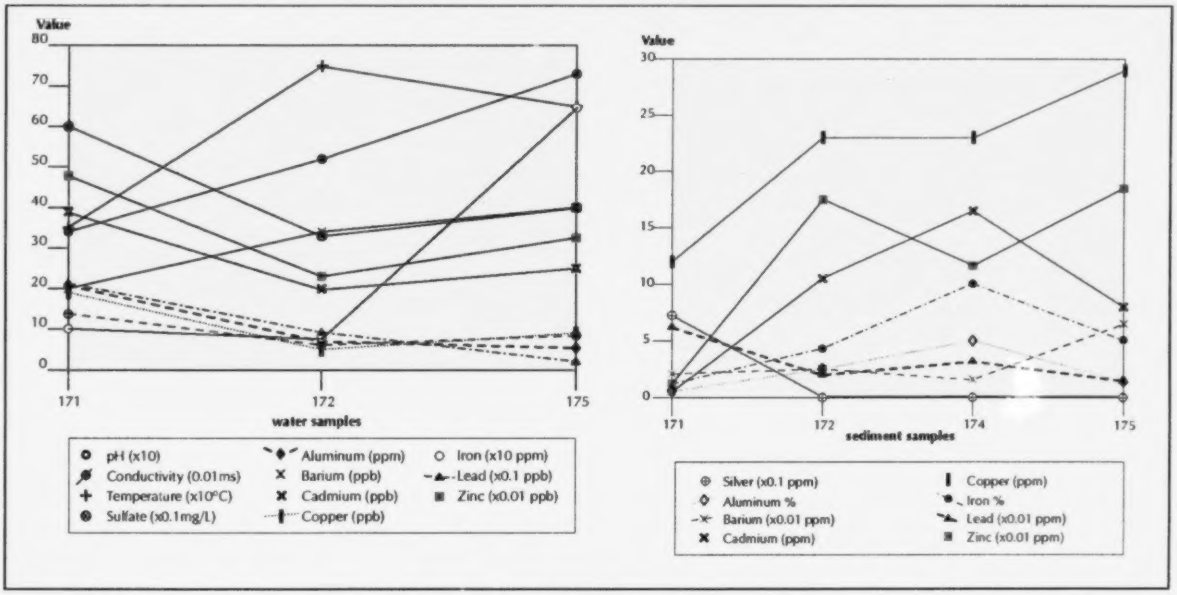

Figure 4. *Graphs of results for Pearl Creek water and sediment samples showing the changes in element concentration with changes in pH.*

***Table 1**. Results of water and sediment analysis divided into acidic, moderately acidic and alkaline suites.*

		Acidic (pH< 4.5)			**Moderately acidic (pH 4.5-6.9)**								**Alkaline (pH > 6.9)**		
SAMPLE	**Detection Limit**	**171**	**170**	**170a (non-acidified)**	**164**	**168**	**172**	**179**	**dup of 179 (SO_4)**	**177**	**178**	**176**	**169**	**dup of 169 (sed)**	**173**
Latitude			61° 28'51"		61° 21'05"	61° 26'12"	61° 19.748	61° 36'46"		61° 38'22"	61° 38'28"	61° 39'40"	61° 27'38"		61° 19.591
Longitude			131° 53'57"		131° 35'42"	131° 41'32"	131° 29.074	132° 25'16"		132° 18'49"	132° 23'28"	132° 21'03"	131° 53'29"		131° 29'23"
Location		105G/6 Pearl Creek	105G/5		105G/5	105G/5	105G/6 Pearl Creek	105F/		105F/	105F/ RAT	105F/	105G/5 @ Cry 138		105G/6 Rusty Creek
pH		3.4	4.4		4.9	5.0	5.2	6.2		6.6	6.6	6.7	7.0	7.0	7.0
Conductivity (ms)		1370	2000		630	1220	620	1630		690	420	670	690		890
Temperature (°C)		3.5	6.0		7.0	5.5	7.5						5.5		6.0
Ag(sed) (ppm)	**0.2**	**72.6**	**0.8**		**1**	**< 0.2**	**0.4**	**0.6**		**0.4**	**0.6**	**0.8**	**< 0.2**	**< 0.2**	**1.4**
Ag(H_2O) (ppb)	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5		64	40	< 5	< 5		< 5
Al(sed) (%)	**0.01**	**0.58**	**1.16**		**3.42**	**1.54**	**2.53**	**1.37**		**1.14**	**1.22**	**2.21**	**4.53**	**3.47**	**2.34**
Al(H_2O) (ppm)	0.1	20.9	87.0	2.9	64.4	35.6	7.0	3.1		8.4	4.0	0.9	10.6		4.4
As(sed) (ppm)	**2**	**4**	**8**		**20**	**18**	**12**	**26**		**22**	**16**	**26**	**14**	**20**	**16**
As(H_2O) (ppb)	30	< 30	34	45	< 30	< 30	< 30	39		< 30	< 30	< 30	< 30		30
B(H_2O) (ppb)	20	20	20		34	20	20	20		20	20	20	20		20
Ba(sed) (ppm)	**10**	**210**	**260**		**100**	**310**	**250**	**950**		**190**	**180**	**190**	**180**	**190**	**350**
Ba(H_2O) (ppb)	20	< 20	< 20	< 20	49	78	34	< 20		34	39	< 20	69		34
Be(sed) (ppm)	**0.5**	**< 0.5**	**0.5**		**1.5**	**0.5**	**2.0**	**2.0**		**0.5**	**0.5**	**1.0**	**3.0**	**3.0**	**0.5**
Be(H_2O) (ppb)	2	4	15	< 2	4	5	< 2	< 2		< 2	< 2	< 2	< 2		< 2
Ca(sed) (%)	**0.01**	**0.09**	**0.07**		**0.2**	**0.21**	**0.26**	**0.07**		**0.19**	**0.14**	**0.6**	**0.33**	**0.37**	**7.76**
Ca(H_2O) (ppm)	0.1	82.5	237.2	187	90.6	103.6	57.7	185.1		88.0	54.7	312.0	99.0		101.8
Cd(sed) (ppm)	**0.5**	**0.5**	**2.5**		**1.5**	**0.5**	**10.5**	**7.0**		**0.5**	**0.5**	**2.0**	**46.5**	**58.5**	**62.5**
Cd(H_2O) (ppb)	2	39	253	148	6	46	20	146		< 2	< 2	< 2	15		31
Ce(H_2O) (ppb)	30	229	3004	73	377	2052	79	67		119	< 30	< 30	98		< 30
Co(sed) (ppm)	**1**	**1**	**6**		**6**	**14**	**12**	**3**		**25**	**24**	**9**	**47**	**58**	**17**
Co(H_2O) (ppb)	5	50	217	< 5	5	58	14	< 5		9	14	< 5	6		< 5
Cr(sed) (ppm)	**1**	**22**	**12**		**10**	**81**	**35**	**2**		**7**	**2**	**12**	**11**	**8**	**17**
Cu(sed) (ppm)	**1**	**12**	**52**		**23**	**32**	**23**	**38**		**43**	**17**	**61**	**39**	**33**	**58**
Cu(H_2O) (ppb)	2	19	223	3	17	16	5	6		8	3	2	6		11
Fe(sed) (%)	**0.01**	**1.20**	**2.42**		**3.01**	**6.55**	**4.32**	**5.18**		**7.21**	**10.30**	**13.15**	**5.34**	**5.30**	**6.63**
Fe(H_2O) (ppm)	0.01	1.01	0.02	0.17	2.08	0.66	0.08	0.21		27.86	6.17	0.07	3.38		9.84
K(sed) (%)	**0.01**	**0.12**	**0.06**		**0.09**	**0.23**	**0.15**	**0.09**		**0.06**	**0.1**	**0.09**	**0.03**	**0.04**	**0.08**
K(H_2O) (ppm)	0.1	1.2	0.3	1.4	1.6	0.7	0.9	1.4		1.1	1.2	0.6	0.5		0.6
La(sed) (ppm)	**10**	**40**	**50**		**50**	**70**	**80**	**240**		**20**	**30**	**40**	**140**	**160**	**30**
Mg(sed) (%)	**0.01**	**0.24**	**0.16**		**0.22**	**0.58**	**0.82**	**0.05**		**0.10**	**0.05**	**0.07**	**0.34**	**0.25**	**4.09**
Mg(H_2O) (ppm)	0.1	50.0	163.7	138.1	7.0	46.9	24.7	106.7		20.6	12.4	60.4	18.6		45.9
Mn(sed) (ppm)	**5**	**85**	**145**		**705**	**280**	**1750**	**615**		**450**	**620**	**340**	**4810**	**6110**	**3150**
Mn(H_2O) (ppm)	0.01	12.52	6.56	3.71	2.26	6.29	4.08	3.62		0.12	0.49	0.01	0.8		0.3
Mo(sed) (ppm)	**1**	**1**	**4**		**6**	**7**	**11**	**13**		**5**	**2**	**8**	**7**	**9**	**5**
Mo(H_2O) (ppb)	5	< 5	8	< 5	5	5	< 5	5		5	< 5	5	8		< 5
Na(sed) (%)	**0.01**	**< 0.01**	**0.01**		**< 0.01**	**< 0.01**	**< 0.01**	**< 0.01**		**< 0.01**	**< 0.01**	**0.01**	**< 0.01**	**< 0.01**	**< 0.01**
Na(H_2O) (ppm)	0.1	0.3	2.9	0.5	0.3	0.6	0.3	0.5		0.4	0.3	0.5	0.3		0.4
Ni(sed) (ppm)	**1**	**8**	**57**		**27**	**54**	**27**	**13**		**44**	**14**	**63**	**169**	**229**	**17**
Ni(H_2O) (ppb)	20	63	1335	247	73	354	21	243		20	23	54	63		< 20
P(sed) (ppm)	**10**	**690**	**790**		**760**	**790**	**630**	**410**		**960**	**1520**	**1930**	**700**	**850**	**340**
P(H_2O) (ppm)	0.02	0.07	0.1	0.03	1.92	0.06	0.03	0.03		0.11	0.05	0.07	0.06		0.06
Pb(sed) (ppm)	**2**	**630**	**16**		**38**	**32**	**214**	**142**		**38**	**76**	**52**	**14**	**20**	**140**
Pb(H_2O) (ppb)	10	214	< 10	< 10	< 10	< 10	94	< 10		< 10	< 10	< 10	< 10		< 10
Sc(sed) (ppm)	**1**	**13**	**3**		**1**	**4**	**2**	**< 1**		**3**	**3**	**6**	**1**	**1**	**1**
Si(H_2O) (ppm)	0.02	13.60	21.62	10.4	12.27	14.94	4.27	10.19		6.55	6.26	5.01	9.73		8.09
Sr(sed) (ppm)	**1**	**7**	**17**		**50**	**51**	**20**	**15**		**45**	**17**	**79**	**32**	**36**	**102**
Ti(sed) (%)	**0.01**	**< 0.01**	**< 0.01**		**< 0.01**	**0.08**	**< 0.01**	**< 0.01**		**< 0.01**	**< 0.01**	**< 0.01**	**< 0.01**	**< 0.01**	**< 0.01**
Ti(H_2O) (ppb)	10	< 10	33	< 10	< 10	20	< 10	< 10		< 10	< 10	< 10	< 10		< 10
V(sed) (ppm)	**1**	**6**	**18**		**12**	**27**	**13**	**2**		**22**	**7**	**21**	**10**	**10**	**6**
Zn(sed) (ppm)	**2**	**118**	**532**		**246**	**176**	**1750**	**1200**		**178**	**190**	**428**	**1420**	**1880**	**6390**
Zn(H_2O) (ppb)	5	4780	15717	11312	419	4385	2300	11150		29	49	72	739		4098
S(H_2O) (ppm)	0.03	196.05	471.3	271	105.36	206.1	92.28	267.72		80.91	58.23	251.91	95.73		134.01
SO_4(H_2O) (ppm)	0.1	600	1380		360	630	330	690	740	210	150	680	248		430

Table 1. *...continued*

	Alkaline (pH > 6.9)											Blanks				
SAMPLE	**175**	**166**	**dup of 166 (H_2O)**	**167 (sed)**	**dup of 167 (sed)**	**180**	**dup of 180 (SO_4)**	**180a (non-acidified)**	**Rerun of 180a**	**174 (sed)**	**165**	**Water blank #1**	**Water blank #2**	**Water blank #3(SO_4)**	**Water blank #4(SO_4)**	**Standard waste water**
Latitude		61° 25'18"				61° 27'34"				61° 19.591	61° 21'48"					
Longitude		131° 41'02"				132° 38'48"				131° 29'23"	131° 35'56"					
Location		105G/5				105F/MM				105G/6 junction	105G/5					
pH	7.3	7.4		7.4	7.4					7.6	8.3					
Conductivity (ms)		920				710				850	520					
Temperature (°C)		4.0								6.5	10					
Ag(sed) (ppm)	**0.8**	**< 0.2**		**< 0.2**	**< 0.2**	**1.6**				**1.2**	**< 0.2**					
Ag(H_2O) (ppb)	< 5	< 5	< 5			< 5		< 5	< 5		5	< 5	< 5			108
Al(sed) (%)	**1.42**	**4.136**		**9.15**	**10.75**	**0.78**				**5.02**	**0.6**					
Al(H_2O) (ppm)	5.4	< 0.1	< 0.1			0.5		0.6	0.5		1.2	< 0.1	< 0.1			0.5
As(sed) (ppm)	**14**	**32**		**26**	**32**	**102**				**8**	**8**					
As(H_2O) (ppb)	< 30	< 30	< 30			< 30		< 30	< 30		30	< 30	< 30			150
B(H_2O) (ppb)	20	20				20					20					
Ba(sed) (ppm)	**650**	**250**		**340**	**310**	**320**				**160**	**90**					
Ba(H_2O) (ppb)	40	37	39			< 20		< 20	< 20		27	< 20	< 20			483
Be(sed) (ppm)	**1.0**	**4.0**		**11.0**	**13.0**	**< 0.50**				**2.0**	**2.0**					
Be(H_2O) (ppb)	< 2	< 2	< 2			< 2		< 2			< 2	< 2	< 2			131
Ca(sed) (%)	**0.48**	**0.52**		**1.05**	**1.17**	**0.06**				**0.09**	**0.18**					
Ca(H_2O) (ppm)	93.2	174.9	176.0			96.3		94.6	95.2		64.3	< 0.1	< 0.1			< 0.1
Cd(sed) (ppm)	**8.0**	**4.0**		**12.0**	**8.5.0**	**0.5**				**16.5**	**< 0.5**					
Cd(H_2O) (ppb)	25	< 2	< 2			< 2		2	2		4	< 2	< 2			100
Ce(H_2O) (ppb)	< 30	< 30	< 30			< 30		< 30	< 30		116	< 30	< 30			< 30
Co(sed) (ppm)	**6**	**15**		**24**	**13**	**< 1**				**8**	**3**					
Co(H_2O) (ppb)	< 5	< 5	< 5			< 5		< 5	< 5		< 5	< 5	< 5			115
Cr(sed) (ppm)	**20**	**30**		**39**	**35**	**< 1**				**25**	**4**					
Cu(sed) (ppm)	**29**	**91**		**112**	**127**	**92**				**23**	**12**					
Cu(H_2O) (ppb)	9	2	12			3		2	2		7	< 2	< 2			111
Fe (%)	**5.07**	**6.44**		**5.33**	**4.93**	**9.65**				**10.05**	**3.53**					
Fe(H_2O) (ppm)	6.46	0.04	0.06			0.13		0.08	0.08		0.33	0.01	0.01			0.61
K(sed) (%)	**0.07**	**0.14**		**0.15**	**0.13**	**0.46**				**0.08**	**0.12**					
K(H_2O) (ppm)	0.6	0.5	0.5			0.9		0.9	0.9		0.3	< 0.1	< 0.1			< 0.1
La(sed) (ppm)	**40**	**480**		**780**	**870**	**40**				**20**	**220**					
Mg(sed) (%)	**0.38**	**0.47**		**0.68**	**0.56**	**0.30**				**0.33**	**0.11**					
Mg(H_2O) (ppm)	40.1	20.9	21.0			26.3		26.0	26.2		20.9	< 0.1	< 0.1			< 0.1
Mn(sed) (ppm)	**725**	**1140**		**2770**	**1040**	**555**				**940**	**1250**					
Mn(H_2O) (ppm)	0.79	< 0.01	< 0.01			< 0.01		< 0.01	< 0.01		0.05	< 0.01	< 0.01			0.52
Mo(sed) (ppm)	**4**	**15**		**11**	**5**	**11**				**9**	**8**					
Mo(H_2O) (ppb)	< 5	5	5			< 5		< 5	< 5		< 5	< 5	< 5			477
Na(sed) (%)	**< 0.01**	**0.01**		**0.01**	**0.01**	**0.01**				**< 0.01**	**< 0.01**					
Na(H_2O) (ppm)	0.5	0.5	0.5			0.3		0.3	0.3		0.3	< 0.1	< 0.1			< 0.1
Ni(sed) (ppm)	**23**	**40**		**39**	**33**	**1**				**16**	**5**					
Ni(H_2O) (ppb)	< 20	< 20	< 20			< 20		< 20	< 20		39	< 20	< 20			434
P(sed) (ppm)	**730**	**810**		**1290**	**1350**	**330**				**420**	**390**					
P(H_2O) (ppm)	0.03	0.03	0.06			0.03		0.04	0.04		0.04	< .02	< .02			0.02
Pb(sed) (ppm)	**156**	**76**		**54**	**58**	**422**				**326**	**18**					
Pb(H_2O) (ppb)	22	< 10	< 10			< 10		< 10	< 10		< 10	< 10	< 10			112
Sc(sed) (ppm)	**2**	**4**		**7**	**6**	**< 1**				**1**	**< 1**					
Si(H_2O) (ppm)	5.64	3.62	3.62			4.36		4.39	4.27		2.77	0.06	0.05			0.16
Sr(sed) (ppm)	**29**	**55**		**100**	**112**	**10**				**12**	**13**					
Ti(sed) (%)	**< 0.01**	**0.06**		**0.08**	**0.06**	**0.04**				**< 0.01**	**< 0.01**					
Ti(H_2O) (ppb)	< 10	< 10	< 10			< 10		< 10	< 10		< 10	< 10	< 10			< 10
V(sed) (ppm)	**14**	**35**		**25**	**20**	**3**				**9**	**3**					
Zn(sed) (ppm)	**1850**	**672**		**1855**	**1500**	**284**				**1165**	**78**					
Zn(H_2O) (ppb)	3250	< 5	< 5			97		96	95		11	< 5	< 5			610
S(H_2O) (ppm)		125.79	125.97			95.82		95.67	93.90	120.93	44.58	< 0.03	0.03			0.06
SO_4(H_2O) (ppm)		410	390			227	239			400	123			< 1	< 1	

STREAM SEDIMENT AND WATER SAMPLES

If the results of stream sediment analyses are to be used in conjunction with those for water analyses variations in the secondary environment must be taken into consideration; for example differences in pH which may cause changes in the trace element content of stream sediments and water (Fletcher and Doyle, 1974). These variations can lead to the suppression of some true anomalies and the generation of false anomalies. For example, Cu and Zn are soluble at low pH, therefore Cu and Zn concentrations in sediments are likely to be low in an acidic environment (Hansuld, 1966; Earle, 1975). This can be seen in Pearl Creek: at the source (sample 171) where the pH is 3.4 the Cu and Zn contents of the water are 19 and 4780 ppb, respectively, and those of the sediment are 12 and 118 ppm respectively; about 250 m downstream (sample 172) where the pH has increased to 5.2 the Cu and Zn content of the water have decreased to 5 and 96 ppb, respectively, and that of the sediment has increased significantly to 23 and 1,750 ppm, respectively. In the MacMillan Pass area, Fletcher and Doyle (1974) and Earle (1975) showed that the threshold value for Zn in stream sediments is four times greater under neutral or slightly alkaline conditions than in strongly acidic (pH < 4.5) streams. This indicates that data for mobile elements should not be interpreted without reference to the pH of the stream and should only be compared with data for streams of similar acidity.

Other elements that are mobile under acidic conditions include Ni, Mn, Cd and Co (Fletcher and Doyle, 1974; Earle, 1975; Cameron, 1977; Goodfellow, 1989). Therefore, under acidic conditions concentrations of these elements are likely to be low in sediment and elevated in water samples.

Less mobile elements such as Pb and Ag are not as significantly influenced by stream pH and are often a useful indicator of proximity to mineralization (e.g., Fletcher and Doyle, 1974; Earle, 1975; Goodfellow, 1989). Results reported by Cameron

Table 2. *Results of water analysis by ICP-MS.*

Trace element values are in parts per billion. Negative values equal not detected at that lower limit.

Sample ID	165	175	179	180
Li	-1	2	3	7
Na	463	720	757	486
Mg	16,700	37,500	103,000	22,900
Al	1,630	5,820	3,070	668
Si	2,240	4,260	7,770	3,430
K	465	962	2,080	1,350
Ca	62,500	86,600	149,000	90,900
Sc	-1	2	3	1
Ti	0.9	1.2	1.8	1.1
V	0.19	0.27	0.09	0.10
Cr	-0.5	0.5	-0.5	-0.5
Mn	55	577	2,800	10
Fe	437	4,910	658	373
Co	0.162	2.449	0.360	0.144
Ni	0.90	6.02	198	1.59
Cu	10	12	5.5	4.3
Zn	65	2,530	8,730	106
Ga	1.18	0.62	2.20	0.25
Ge	0.20	0.09	0.90	0.09
As	1.06	1.19	2.09	1.54
Se	1.1	1.7	2.8	1.2
Br	5	6	6	-3
Rb	0.528	1.884	3.340	3.186
Sr	149	331	304	124
Y	9.412	9.502	70.98	8.468
Zr	0.170	0.131	0.433	0.499
Nb	0.01	0.02	0.01	0.02
Mo	0.5	0.5	0.1	0.5
Ru	-0.02	-0.02	-0.02	-0.02
Pd	-0.02	-0.02	-0.02	-0.02
Ag	-0.2	-0.2	-0.2	-0.2
Cd	0.43	25.7	155	2.34
In	-0.001	0.152	0.002	-0.001
Sn	0.1	0.3	-0.1	0.2
Sb	0.06	0.18	0.08	0.18
Te	-0.2	-0.2	-0.2	-0.2
I	1.0	1.1	1.1	0.9
Cs	0.116	0.046	0.007	0.258
Ba	28	38	9.8	19
La	81.18	15.09	513.7	17.01
Ce	95.9	22.9	57.5	10.6
Pr	14.64	4.174	70.07	4.787
Nd	48.33	16.71	234.4	17.45
Sm	7.727	4.622	36.99	4.081
Eu	0.938	1.165	4.232	0.511
Gd	9.790	5.146	48.21	4.062
Tb	0.796	0.573	4.163	0.516
Dy	2.319	2.406	14.26	2.426
Ho	0.257	0.307	1.781	0.330
Er	0.630	0.722	4.154	0.802
Tm	0.045	0.076	0.299	0.080
Yb	0.293	0.495	1.690	0.428
Lu	0.040	0.070	0.237	0.047
Hf	0.020	0.023	0.123	0.027
Ta	-0.01	-0.01	0.01	-0.01
W	-0.02	0.24	-0.02	-0.02
Re	0.002	0.002	0.001	0.005
Os	-0.002	-0.002	-0.002	-0.002
Pt	-0.02	-0.02	-0.02	-0.02
Au	-0.002	-0.002	-0.002	-0.002
Hg	-0.2	-0.2	-0.2	-0.2
Tl	0.015	0.381	0.016	0.011
Pb	2.3	35	4.2	2.6
Bi	0.034	0.042	0.021	0.015
Th	0.040	0.321	0.081	0.208
U	0.181	1.646	0.052	0.942

(1977) for samples of water and sediment collected near massive sulphide mineralization in the Agricola Lake area, NWT, show that Pb, Ag and Hg are immobile in the surface environment and are largely retained in soils near the mineralization. However, Zn, Cd and Cu are mobile and are dispersed far along the lake-stream system draining the mineralization.

In order to compare streams throughout the Pelly Mountains volcanic belt, variations in pH were taken into account and the samples were divided into highly acidic (pH < 4.5), moderately acidic (pH 4.5 to 6.9) and alkaline (pH > 6.9) suites as suggested by Fletcher and Doyle (1974) and shown in Table 1.

Samples 171, 172, 174 and 175 are from Pearl Creek which drains the Wolf Zn-Pb-Ag deposit. These samples all have elevated Pb and Zn values. Water sample 171 also has an elevated sulphate content. Sample 179, which was collected near the Fire (Chzerpnough) prospect, has elevated Pb and Zn levels plus Ni, Cd and sulphate. Sample 180 was collected from a creek draining the MM barite-pyrite ± sphalerite ± galena ± chalcopyrite deposit. It has elevated Pb, Ag and Cu levels but low levels of Zn in sediment and water samples. This sample was the only one collected that had an elevated level of As.

The remaining samples were not collected near any known mineralization. For samples 168 and 170, shale may be the source of zinc as the samples also have elevated levels of As, Co, Ni and sulphate, and were collected close to the contact between the volcanic rocks and the underlying carbonate/shale sequence. Similar shales are known to produce anomalous zinc values in the Driftpile Creek (Lett et al., 1997) and MacMillan Pass areas (Earle, 1975). Of the remaining samples with elevated values (all in sediment: **164**: Ag; **166**: Cu; **167**: Cu Zn; **169**: Cd, Co, Ni, Zn; **176:** Cu Fe, SO_4), samples 167, 169 and 176 are the most interesting as they have multiple element anomalies.

The data in Table 1 also shows that there is a close correlation between the concentration of Mn in water and the increase in pH; the Mn content of water decreases as the pH increases. This relationship is similar to that documented by Fletcher and Doyle (1974) for the MacMillan Pass area.

The results of sulphate analysis for the water samples show that overall, the sulphate content of the water decreases as the pH increases; the S content also decreases overall. Sulphate is most soluble in acidic waters and the decrease in sulphate content is likely due to the precipitation of aluminium and/or barium sulphates as the waters become increasingly alkaline.

COMPARISON TO EXISTING RGS DATA

Regional geochemical stream sediment samples (RGS) were collected at an average density of one sample per 13 square km throughout the Pelly Mountains volcanic belt (Fig. 2; Hornbrook and Friske, 1985, 1988). The RGS samples located proximal to the volcanic belt have pH values ranging from 7.0 to 8.4 and should therefore only be compared to sediment samples from creeks of similar alkalinity. This comparison reveals that at the southeast end of the belt only one RGS sample is anomalous (1085 on NTS 105G) with elevated values of Zn, Cu and Cd. The remainder of the belt (NTS 105F) has several anomalous RGS samples (**1090** - Zn, Pb, Ag, Cd; **1110** and **1203** - Cu; **1122, 1123** and **1188** - Pb; **1206** - Pb, Ag).

All of the RGS samples have barium contents significantly greater than samples from the present study. This, plus the high pH values, may be an indication that the RGS samples were collected in creeks that drain older platformal strata and do not directly drain the volcanic belt .

CONCLUSIONS

Preliminary results of spring/creek water sample analysis reveal:

- The creek draining the Wolf deposit varies in pH from 3.4 to 7.6 and has elevated levels of Pb and Zn in water and sediment samples. Changes in the element content of water and sediment samples occur over short distances as the pH changes indicating that the location of a given sample is important if samples from various creeks are to be compared.
- Creeks draining areas of known mineralization have elevated base metal content in water and/or sediment samples indicating that this may be a viable exploration method for locating VMS mineralization in the Pelly Mountains volcanic belt.
- A creek draining the MM deposit (sample 180) has a pH of 7.5 and elevated levels of Ag, Cu and Pb in sediment but not in water, and Zn is not elevated.
- A creek draining the Fire pyrite-barite occurrence (sample 179) has a pH of 6.2 and elevated levels of Ba, Pb and Zn in sediment and Cd, Ni and Zn in water.
- Several samples from creeks not located near any known mineralization (samples 164, 166, 167, 169, 176) returned elevated values of Cu and Zn suggesting the presence of pyritic shale, or possibly, undiscovered mineralization.
- The white precipitate in the creeks is likely composed of aluminium hydroxide or aluminium and calcium sulphate, and indicates an acidic environment, at least locally. The precipitate likely occurs where there are rapid pH changes and can be indicative of base metal mineralization.

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REFERENCES

Cameron, E.M., 1977. Geochemical dispersion in lake waters and sediments from massive sulphide mineralization, Agricola Lake area, Northwest Territories. Journal of Geochemical Exploration, vol. 7, p. 327-348.

Earle, S.A.M., 1975. Copper, lead and zinc stream sediment geochemistry and effects of secondary environment, Nahanni map area, Yukon and Northwest Territories. Unpublished B.Sc. Thesis, University of British Columbia, Vancouver, B.C., 120 p.

Fletcher, W.K. and Doyle, P., 1974. Factors influencing trace element distribution in the eastern Yukon. Canadian Institute of Mining and Metallurgy, Bulletin, vol. 77, p. 27-31.

Gibson, A.M., Holbek, P.M. and Wilson, R.G., 1999. The Wolf property — 1998 update: Volcanogenic massive sulphides hosted by rift-related, alkaline, felsic volcanic rocks, Pelly Mountains, Yukon. *In:* Yukon Exploration and Geology 1998, C.F. Roots and D.S. Emond (eds.), Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 237-242.

Gordey, S.P., 1977. Stratigraphy, structure and tectonic evolution of the southern Pelly Mountains in the Indigo Lake area, Yukon Territory. Unpublished Ph.D. thesis, Queen's University, Ontario, Canada, 200 p.

Gordey, S.P., 1981. Stratigraphy, structure and tectonic evolution of southern Pelly Mountains in the Indigo Lake area, Yukon Territory. Geological Survey of Canada, Bulletin 318, 44 p.

Goodfellow, W.D., 1989. Interpretation of stream geochemistry leading to the discovery of a secondary zinc deposit, Pelly River, Nahanni map area, Yukon. *In:* Current Research, Part E, Geological Survey of Canada, Paper 89-1E, p. 31-50.

Hansuld, J.A., 1966. Eh and pH in geochemical exploration. Canadian Institute of Mining and Metallurgy, Transactions, vol. 1, LXIX, p. 77-84.

Hoag, R.B. and Webber, G.R., 1976. Significance for mineral exploration of sulphate concentrations in ground waters. Canadian Institute of Mining and Metallurgy, Bulletin, vol. 79, p. 86-91.

Hornbrook, E.H.W. and Friske, P.W.B., 1985. Regional stream sediment and water geochemical data, southeastern Yukon. Geological Survey of Canada, Open File 1290 (105F).

Hornbrook, E.H.W. and Friske, P.W.B., 1988. Regional stream sediment and water geochemical data, southeastern Yukon. Geological Survey of Canada, Open File 1648 (105G).

Lett, R.E. and Jackaman, W., 1995. Application of spring-water chemistry to exploration in the Driftpile Creek area, northeastern B.C. (94K/4, 94L/1). British Columbia Ministry of Energy and Mines, Geological Survey Branch, Geological Fieldwork 1994, Paper 1995-1, p. 269-275.

Lett, R.E., Cook, S.J., Sibbick, S. and Jackaman, W., 1997. Geochemical exploration tools for shale-hosted lead-zinc-silver deposits in northeastern British Columbia. *In:* New frontiers for the next century, 99th CIM Annual General Meeting, Vancouver, B.C., CIM '97 Abstracts, CD-ROM.

Morin, J.A., 1977. Ag-Pb-Zn mineralization in the MM deposit and associated Mississippian felsic volcanic rocks in the St. Cyr Range, Pelly Mountains. *In:* Mineral Industry Report, 1976, Yukon Territory. EGS 1977-1, p. 83-97.

Mortensen, J.K., 1979. Stratigraphic, structural, and tectonic setting of an Upper Devonian-Mississippian volcanic sedimentary sequence and associated base metal deposits in the Pelly Mountains, southeastern Yukon Territory. Unpublished M.Sc. thesis, University of British Columbia, 122 p.

Mortensen, J.K., 1982. Geological setting and tectonic significance of Mississippian felsic metavolcanic rocks in the Pelly Mountains, southeastern Yukon Territory. Canadian Journal of Earth Sciences, vol., 19, p. 8-22.

Sibbick, S., 1995. Prediction of acid rock drainage prone regions using regional geochemical survey data. Paper presented at Sudbury '95, Conference on Mining and the Environment, Sudbury, Ontario, Canada.

Tempelman-Kluit, D.J., Abbott, G., Gordey, S.P. and Read, B., 1975. Stratigraphic and structural studies in the Pelly Mountains, Yukon Territory. Geological Survey of Canada, Paper 75-1, Part A, p. 45-48.

Tempelman-Kluit, D.J., Gordey, S.P. and Read, B.C., 1976. Stratigraphic and structural studies in the Pelly Mountains, Yukon Territory. Geological Survey of Canada, Paper 76-1, Part A, p. 97-106.

Tempelman-Kluit, D.J., 1977 a. Stratigraphic and structural relations between the Selwyn Basin, Pelly-Cassiar Platform, and Yukon Crystalline Terrane in the Pelly Mountains, Yukon. Geological Survey of Canada, Paper 77-1A, p. 223-227.

Tempelman-Kluit, D.J., 1977 b. Quiet Lake and Finlayson Lake map sheets. Geological Survey of Canada, Open File 486.

Wheeler, J.O. and McFeely, P., 1991. Tectonic Assemblage map of the Canadian Cordillera and adjacent parts of the United States of America. Geological Survey of Canada, Map 1712A, 1: 2 000 000 scale.

Wheeler, J.O., Green, L.H. and Roddick, J.A., 1960 a. Sheet 105F - Quiet Lake map area. GSC Map 7-1960.

Wheeler, J.O., Green, L.H. and Roddick, J.A., 1960 b. Sheet 105G - Finlayson Lake map area. GSC Map 8-1960.

Yukon Minfile. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada. Also available from Hyperborean Productions, Whitehorse, Yukon.

APPENDIX A

SAMPLE SITE DESCRIPTIONS

Sample 164 - Water and silt samples were collected from a creek with white precipitate, 1 m upstream from the junction with a rusty creek.

Sample 165 - Water and silt samples were collected from a creek with white precipitate, about 20 m below a lake outlet.

Sample 166 - Water and silt samples were collected from a creek with white precipitate, below the area of white precipitate.

Sample 167 - Silt sample collected from the same site as 166, but upstream in the area of white precipitate.

Sample 168 - Water and silt samples were collected from a creek with white precipitate, near the source at the point where there was a change from white to rusty precipitate downstream.

Sample 169 - Water and silt samples were collected from a creek with white precipitate, near the source at the point where there was a change from white to rusty precipitate downstream.

Sample 170 - Water and silt samples were collected from a seep flowing over argillite, at the first appearance of a white precipitate.

Sample 171 - Water and silt samples were collected from the source of Pearl Creek, which drains the Wolf deposit. There is no white precipitate at the source.

Sample 172 - Water and silt samples were collected from a site about 100 m downstream of 171, where white precipitate first appears.

Sample 173 - Water and silt samples were collected from Red Creek, which joins Pearl Creek, about 400 m downstream from its source.

Sample 174 - A silt sample was collected from Pearl Creek, at the junction with Red Creek.

Sample 175 - Water and silt samples were collected from immediately below the confluence of Pearl and Red creeks.

Sample 176 - Water and silt samples were collected from the rusty part of the creek, upstream from a white precipitate, north of Chzerpnough prospect.

Sample 177 - Water and silt samples were collected from a small creek near a seep, Chzerpnough prospect.

Sample 178 - Water and silt samples were collected from the Rat claims, close to a seep with white precipitate in the creek. The creek was rusty above the white precipitate.

Sample 179 - Water and silt samples were collected from the head of a creek, just above where white precipitate occurred. The head of the creek is swampy.

Sample 180 - Water and silt samples were collected from a creek on the MM property, at the contact between rusty and white precipitate.

New paleontological investigations of Upper Triassic shallow-water reef carbonates (Lewes River Group) in the Whitehorse area, Yukon

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ABSTRACT

The thickest and best-developed Upper Triassic reef complex in the entire North American Cordillera is at Lime Peak in the southern Yukon. The Lime Peak reef complex is a Dachstein-type, Tethyan reef that lies within Whitehorse Trough stratigraphy of Stikinia, an inboard island-arc terrane of unknown Mesozoic paleogeography. Initial studies of Lime Peak reef faunas revealed characteristics similar to other North American Triassic reefs. Our investigation attempts to better define these paleontological relationships and establish paleobiogeographical associations.

Paleontological samples from five carbonate localities within the Lewes River Group contain corals, sponges, brachiopods, bivalves, disjectoporids, and spongiomorphs. For this study, corals and giant bivalves are identified and compared with fauna from Triassic reef deposits found in the Chulitna (Alaska), Quesnel (southern BC), Wallowa and Western Great Basin (western US), and Antimonio (Mexico) terranes. Preliminary field observations in the Yukon confirm the presence of *Wallowaconchid* bivalves known previously only from the Wallowa and Antimonio, and systematic analysis of Lime Peak corals identified seven species common in the Quesnel, Wallowa, or Antimonio terranes. These findings demonstrate that reef fossils found in the Whitehorse Trough of southern Yukon constitute an important paleobiogeographical link between Stikinia and other exotic terranes of the Cordillera.

RÉSUMÉ

Le complexe récifal du Trias supérieur le plus épais et le mieux formé de la Cordillère nord-américaine est situé à Lime Peak dans le sud du Yukon. Ce complexe est un récif téthysien de type Dachstein inclus dans la stratigraphie de la dépression de Whitehorse située dans le terrane d'arc insulaire intérieur de Stikinia dont la paléogéographie du Mésozoïque n'est pas connue. Les échantillons paléontologiques prélevés dans cinq zones à roches carbonatées du Groupe de Lewes River renferment des coraux, des éponges, des brachiopodes, des lamellibranches, des disjectoporoïdes et des spongiomorphes. Aux fins de la présente étude, les coraux et les lamellibranches géants sont identifiés, puis comparés avec la faune des dépôts récifaux du Trias se trouvant dans les terranes de Chulitna (Alaska), de Quesnel (sud de la Colombie-Britannique), de Wallowa, de la partie occidentale du Grand Bassin (ouest des États-Unis) et d'Antimonio (Mexique). Les premières observations de terrain effectuées au Yukon confirment la présence de lamellibranches de Wallowaconchide connues antérieurement dans les terranes de Wallowa et d'Antimonio. L'analyse systématique des coraux de Lime Peak a mis en évidence sept espèces communes aux terranes de Quesnel, de Wallowa et d'Antimonio. Ces résultats montrent que les fossiles récifaux trouvés dans la dépression de Whitehorse (sud du Yukon) constituent un lien paléobiogéographique important entre le terrane de Stikinia et les autres terranes allochtones de la Cordillère.

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INTRODUCTION

The North American Cordillera contains numerous Triassic carbonate buildups that once rimmed islands in the paleo-Pacific Ocean, and are now accreted along the continental margin. Although studied less intensely, coral and other reef fauna found in these buildups show similarities to "Tethyan" fossil reefs in Eurasia (Stanley and Senowbari-Daryan, 1986; Reid and Tempelman-Kluit, 1987; Stanley, 1994). However, because of poor development, smaller size, and limited research, little is known about the evolution and paleogeography of North American Triassic reefs. Continued analysis and comparison of Cordilleran reefs will create the basis for a model, analogous to the classic "Tethyan" reef model, of Triassic reef evolution and paleogeography in North America.

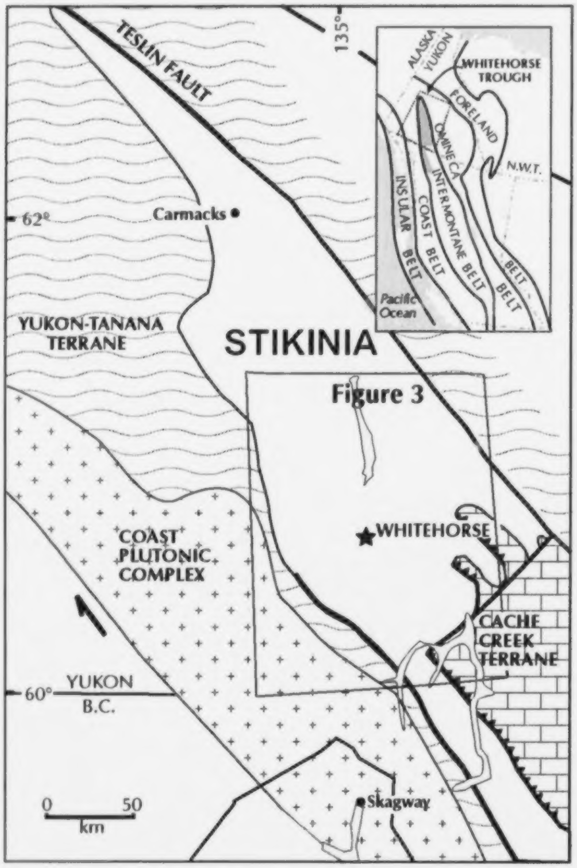
TESLIN FAULT
135°
ALASKA
YUKON
WHITEHORSE TROUGH
FORELAND
OMINECA
N.W.T.
INSULAR BELT
COAST BELT
INTERMONTANE BELT
BELT
BELT
Pacific Ocean
62°
Carmacks
YUKON-TANANA TERRANE
STIKINIA
Figure 3
WHITEHORSE
COAST PLUTONIC COMPLEX
CACHE CREEK TERRANE
60°
YUKON
B.C.
0
50
km
Skagway

Figure 1. *Regioinal tectonic setting of the study area in Stikinia of southern Yukon. Inset map shows location of Whitehorse Trough with respect to the Cordilleran physiographic belts. Much of Stikine Terrane is underlain by the Intermontane Belt.*

Fieldwork was conducted in the Whitehorse area as part of a research project on North American Triassic reef deposits. The goal is to investigate Triassic carbonate deposits of the northern Stikine Terrane (a.k.a. Stikinia) to better understand their paleoecology and paleogeography. Lime Peak and four other carbonate localities, Pilot Mountain Subdivision, Emerald Lake, Grey Mountain, and upper Cap Creek, were examined and sampled for paleontological specimens.

This report presents primary observations and analysis of the paleontology of the Stikine Terrane and its relationship to Cordilleran paleogeography. Through paleontological associations, a paleobiogeographical link between Stikinia and other displaced terranes of North America is formed. This relationship is important in the reconstruction of a Triassic paleogeography for rocks in the Cordillera.

REGIONAL GEOLOGY

Much of the Canadian Cordillera is composed of disparate crustal fragments called terranes, whose origins, prior to their accretion to the western margin of North America, are suspect. Among the largest of these suspect terranes is Stikine Terrane. In the Yukon, Stikine Terrane is composed of a Paleozoic poly-metamorphosed basement assemblage (Stikine Assemblage), upon which a Mesozoic arc, fore-arc and marginal basin assemblage was built and deposited. Middle Triassic tholeiites and Late Triassic calc-alkaline basalts of the Joe Mountain and Povoas Formations respectively, comprise the dominantly volcanic portions of the arc (Hart, 1997). Whitehorse Trough (Fig. 1), the arc marginal basin, was the depocentre for approximately seven kilometres of largely arc-derived clastic rocks that accumulated during Upper Triassic to Middle Jurassic time (Wheeler, 1961). This sedimentary package, the Whitehorse Trough Supergroup, is divisible into Triassic (Aksala Formation-Lewes River Group) and Jurassic

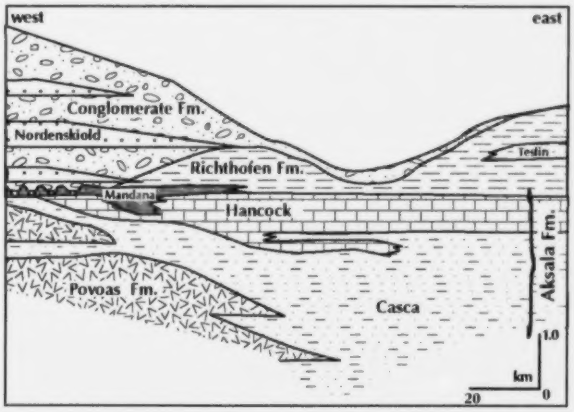
west
east
Conglomerate Fm.
Nordenskiold
Richthofen Fm.
Teslin
Mandana
Hancock
Povoas Fm.
Casca
Aksala Fm.
1.0
km
20
0

Figure 2. *Generalized stratigraphic section of Whitehorse Trough. Fossils are hosted in the Upper Triassic Hancock Member limestone.*

(Laberge Group) stratigraphic packages (Fig. 2) that are separated by an erosional disconformity along the western margin of the Trough (Hart, 1997).

The upper portion of the Aksala Formation is characterized by thick units of massive carbonate that distinguish the Hancock Member. The age range of this member, as constrained by conodonts and macrofossils, is limited to the upper Norian (Hart, 1997). However the occurrence of Mysidioptera sp. in limestone-rich sections (Formation "C" of Tozer, 1958; Wheeler, 1961, p. 33) indicates that some carbonate buildups are possibly Late Carnian in age. The thick carbonate sequences are within the dominantly clastic Aksala Formation and represent quiescent depositional episodes.

Thick accumulations of carbonate are characterized by massive, resistant weathering, but rounded topography and occurrences are plentiful in the southern Yukon. In the Whitehorse area, the Upper Triassic limestone forms Grey Mountain and is responsible for hosting copper-gold-silver skarn mineralization adjacent to the mid-Cretaceous Whitehorse Pluton.

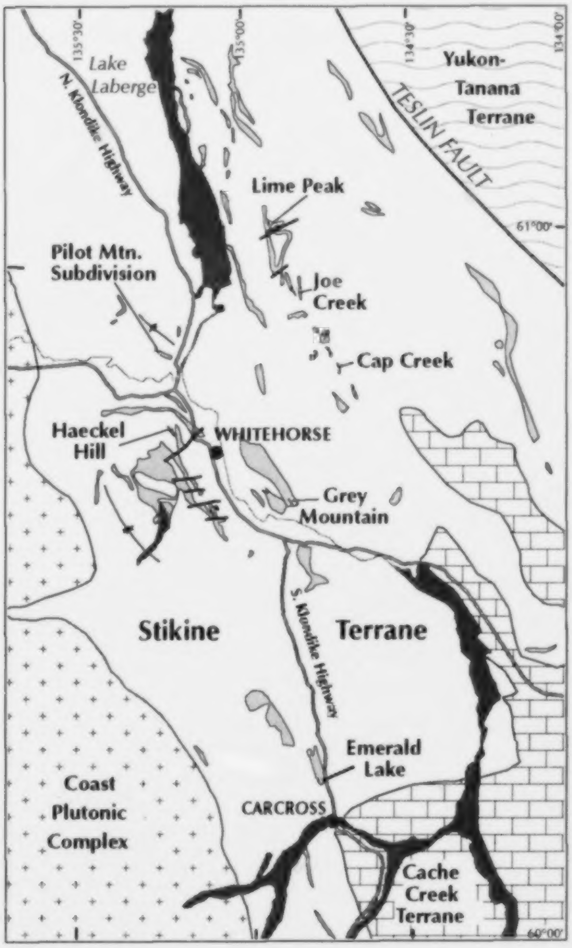

Figure 3. *Upper Triassic carbonate (Hancock Member) (shaded) in the southern Yukon, and fossil localities mentioned in this report.*

PALEONTOLOGY

Carbonate units outcrop throughout the Whitehorse Trough in the southern Yukon (Fig. 3) but occurrences with well-preserved macrofossils are less common. We document five localities in the southern Yukon with diverse faunas and fair to good preservation — Lime Peak, Pilot Mountain Subdivision, Emerald Lake, Grey Mountain, and upper Cap Creek. Each locality was selected for its abundance of carbonate rock outcrop and the presence of fairly well preserved fossils. Paleontological samples were collected from each location, and the condition of the rock was observed. The age of each locality is determined as Upper Triassic, based on fossil assemblages and adjacent stratigraphy.

LIME PEAK

Located approximately 40 km northeast of Whitehorse, on the north side of Thomas Lake, Lime Peak (Fig. 4) (61°03.5'N, 134°54'W; NTS 105E/2) is the thickest and most fossiliferous accumulation in the Whitehorse Trough. The facies and evolution of Lime Peak are well documented by Reid (1985) who recognized the exposure as representing a series of shallow-water reefs and intervening bedded lagoonal or interreef environments. The diverse assemblage of chambered and nonchambered thalamid sponges also is studied (Senowbari-Daryan and Reid, 1986; Reid and Tempelman-Kluit, 1987). They noted that most of the "reef limestone" consists of several smaller bodies or patch reefs. In many respects the Lime Peak complex is somewhat similar to the Dachstein Reef Limestone

Figure 4. *Aerial view, looking north, towards the Lime Peak Reef complex. Thomas Lake is in the foreground.*

of the Northern Calcareous Alps of Austria and southern Germany (Zankl, 1968).

Our investigation focused on the massive, light brown and unbedded limestone facies where most of the fair-to-well preserved reefal fauna are located. The fossil biotas sampled and observed at Lime Peak include sponges, spongiomorphs, tabulozoans, disjectoporids, scleractinian corals, algae, brachiopods, and molluscs. Recent, unconfirmed coral identifications show the presence of *Gablonzeria* sp., *Chondrocoenia* sp., *Distichomeandra* sp., *Crassistella* sp., *Procyclolites* sp., *Astraeomorpha* sp., and *Retiophyllia* sp. at Lime Peak.

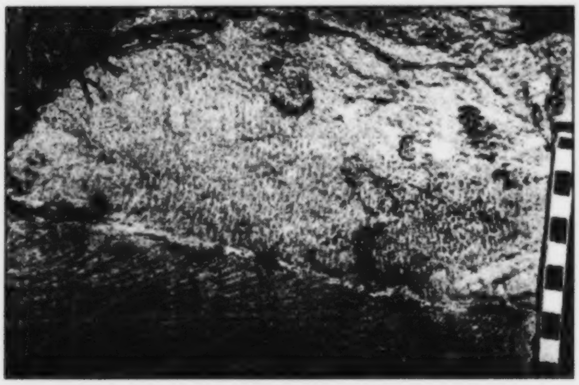

Figure 5. *Retiophyllia oppeli colony in outcrop at Pilot Mountain Subdivision. Scale is in centimetres.*

PILOT MOUNTAIN SUBDIVISION

This locality (60°52'00"N, 135°13'11"W; NTS 105 D/14), occurs as a linear, 10 m wide exposure that outcrops at its intersection with the hydro line service road, north of the Pilot Mountain subdivision off of the Takhini Hotsprings road. The exposure is less impressive than Lime Peak, but just as important. The limestone is massive and appears slightly silicified. The fossils collected include [illegible] sponges, tabulozoans, and brachiopods. Initial identification of a coral from this locality (Fig. 5) indicates the presence of *Retiophyllia oppeli* (Reuss).

EMERALD LAKE

Located approximately 48 km south-southeast of Whitehorse (60°15'44"N, 134°45'28"W; NTS 105 D/7), this locality is exposed along the western side of the south end of Emerald Lake. Access is a short hike from a pull-off along the South Klondike Highway. Outcrop is a steeply east-dipping limestone face that forms the eastern limb of a north-striking anticline. The limestone is massive and quite fossiliferous; however, the nature of the outcrop makes sampling difficult. Samples representing a diverse fauna were collected, such as brachiopods, spongiomorphs, crinoids, thick-shelled oysters, corals, gastropods, inozoan sponges, and the "winged" bivalve known as *Wallowaconchid*. Due to recrystallization, preservation of corals and sponges is poor, however, two brachiopods were identified as *Spondylospira lewesensis* (Lees) and *Terebratulid* sp. and the oyster is *Lopha*. These three species are also found at Lime Peak.

GREY MOUNTAIN

The Grey Mountain locality lies east of Whitehorse (60°39'25"N, 134°53'20"W; NTS 105 D/10) and is shown on many maps as

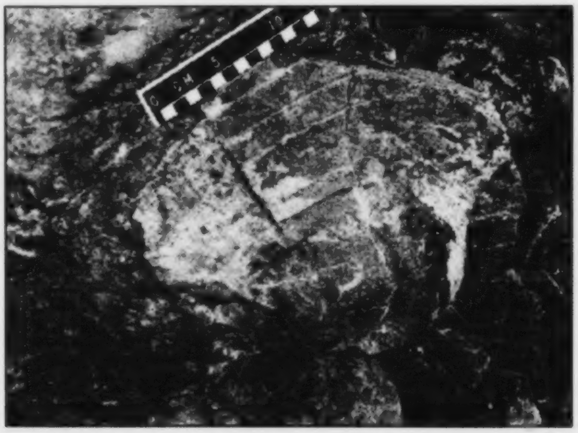

Figure 6. *Large, "whole" Wallowaconchid bivalve at Grey Mountain. View is looking down at its top, at an oblique angle. Scale is in centimetres.*

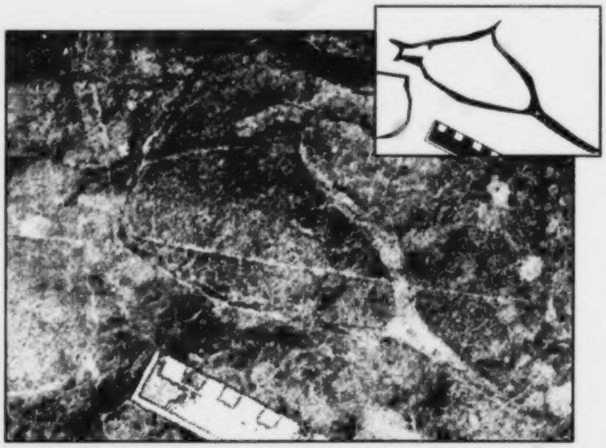

Figure 7. *Cross-sectional view of a Wallowaconchid bivalve at Grey Mountain. Note characteristic "wings" and their segmentations. Scale is in centimetres.*

Canyon Mountain. Access is by a rough gravel road used to access communications towers at the south end. The limestone is massive, and light grey weathering but appears blackish and recrystallized on fresh surfaces. Exposure is generally continuous with intermittent covered intervals. A limited but significant fauna is observed, including abundant *Wallowaconchids* and thickets of large and small sized *Retiophyllia* coral (Figs. 6 and 7). The *Wallowaconchid* "wings" measure 28 and 30 cm in length, and the *Retiophyllia* are dendroid and without connecting processes. The appearance of the *Retiophyllia* suggest a low energy, possibly lagoonal, depositional environment for this limestone.

CAP CREEK

Accessible only by helicopter, the Cap Creek locality (60°51'19"N, 134°41'45"W; NTS 105 D/15) is near the upper reaches on the east side of Cap Creek. Limestone outcrops form dark grey, massive beds with covered intervals underlain by shales and mudstones. Fossils observed and sampled include bivalves, sponges, spongiomorphs, Distichophyllid corals, and gastropods. East of the limestone outcrop, a thinly laminated mudstone, indicative of deeper water depositional environment, contained a bed of *Monotis* sp. bivalves. Preliminary identification of the sponges finds probable *Nevadathalamia* sp. and *Cinnabaria* sp. similar to those found at Lime Peak. This locality produced a conodont assemblage defined as Late Norian (site T-20 of Hart, 1997).

DISCUSSION

The Whitehorse area is unique in having well-developed Upper Triassic (Norian) carbonates which also contain thick reef complexes. Similar reef complexes of equivalent age are known from far-flung sites in the Cordilleran terrane collage including in northwestern Oregon, the Wallowa Terrane (Stanley and Senowbari-Daryan, 1986) and from central British Columbia, Quesnel Terrane, the Eaglenest reef (Stanley and Nelson, 1996).

The five localities investigated for this project are stratigraphically and paleontologically related and together reveal important information. Paleontological examination of fossil corals and giant alloform bivalves from the Stikine Terrane of the southern Yukon indicate the presence of species that show a possible link with other exotic terranes of the North American Cordillera. Six coral species, initially identified from Lime Peak and nearby carbonate deposits, are also known from the Quesnel, Wallowa, Western Great Basin, and Antimonio terranes (Table 1). However, coral and other fossils from the same deposits also show Tethyan, or European affinities (Reid and Tempelman-Kluit, 1987). A seventh coral sampled from Lime Peak and identified as *Procyclolites triadicus* Frech, is classified as Tethyan and is commonly found in fossil reef deposits in the Alps.

The large, "winged" bivalve, *Wallowaconcha raylenea* is unequivocally known at two of the five reported Yukon locations (Grey Mountain and Emerald Lake), as well as two unreported locations (Haeckel Hill, 60°45'25"N, 135°12'25"W; Joe Creek, 60°59'10"N, 134°52'30"W; sites T-7 and T-9 respectively of Hart, 1997). The same species of *Wallowaconcha* also is reported from the Wallowa Terrane in northeastern Oregon), and a smaller, and yet indeterminate species, recently has been discovered from the Chulitna Terrane of Alaska (Stanley and Yarnell, in prep.). The Alaskan species appears also to occur in the Antimonio Terrane, Sonora, Mexico. These giant wallowaconchid bivalves constitute a unique tropical element, known only from the Norian stage of the Upper Triassic and endemic only to a few Cordilleran terranes. Reaching up to a meter in breadth, these bivalves lived in fine-grained muds. They are termed "alatoform" because unlike most bivalves, they lie flat on the substrate with their commissures oriented vertically. They were especially adapted to reef environments and appear to have inhabited lagoons. Wing-like extensions from the main body chamber surround the shell with series of tubes, appearing in cross section, like chambers. These chambers are interpreted as housing symbiotic algae. Like reef corals and molluscs today, these symbiots most likely benefitted the metabolism of the host and the growth of the large shells.

These tropical, specialized wallowaconchids constitute a new family, entirely unknown from any of the numerous Upper Triassic (Norian) reef localities in the former Tethys region. They

Table 1. *Geographic distribution of Upper Triassic fossils in the North American Cordillera.*

Taxa	Chulitna	Stikine	Quesnel	Wallowa	Western Great Basin Terrane	Antimonio
CORAL						
Astraeomorpha sp.		X			X	X
Chondrocoenia sp.		X	X		X	X
Crassistella sp.		X		X	X	
Distichomeandra sp.		X			X	X
Gablonzeria sp.		X		X	X	X
Retiophyllia sp.	X	X		X	X	X
BIVALVE						
Wallowaconcha sp.	X	X		X		X

are also unknown from the North American craton. Because of their restricted, endemic nature, most likely reflecting a limited ability to disperse, these bivalves appear important for reconstructing the Upper Triassic paleogeography of Tethys.

CONCLUSION

Sedimentology and stratigraphic documentation of the spectacular Upper Triassic reef at Lime Peak by Reid (1985) was followed-up with a detailed taxonomic study of sponges found there (Senowbari-Daryan and Reid, 1987). Corals and other elements of the fauna are in need of study and appear useful in paleogeographic analysis. Although somewhat smaller and less well exposed than at Lime Peak, Upper Triassic reef carbonates are fairly common throughout the Whitehorse Trough.

Our investigations of Upper Triassic Stikine Terrane (Whitehorse Trough) carbonates indicate paleontological similarities with other terranes in Alaska, British Columbia, and the United States and suggest paleogeographical proximity during their deposition as coral and reef-fringed volcanic islands in the ancient Pacific Ocean). Since their accretion to North America, most terranes have been dislocated from their original paleolatitudes. Some were rotated and most were moved far from the tropics by extensive transcurrent or strike-slip faults which further modified the rock assemblages along the western edge of the North American Cordillera. These tectonic complexites complicates correlation and matching of terranes, and the reconstruction of their pre-accretion paleogeography.

Paleogeographic models based on fossils of the Permian and Jurassic show Stikinia in the northern hemisphere in the tropical eastern Pacific, some distance from North America. The presence of abundant Tethyan fossil taxa among the carbonates of the Whitehorse Trough also indicates a paleogeographical link between Stikinia and the Tethys. These associations so far from the western reaches of the Pacific seem problematic. Such distributions may indicate the dispersal abilities of some invertebrates in conjunction with changing patterns of terrane geography through time (Westermann et al., 1990). Continued research and study of the taxonomy of Triassic reef fossils in Yukon and throughout the Western Cordillera will improve an understanding of Triassic reef paleogeography and paleoecology.

REFERENCES

Hart, C.J.R., 1997. A transect across northern Stikinia: Geology of the northern Whitehorse map area, southern Yukon Territory (105D/13-16). Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, Bulletin 8, 112 p.

Reid, R.P., 1985. The facies and evolution of an Upper Triassic reef complex in northern Canada. Unpublished Ph. D. thesis, University of Miami, Miami, Florida, 437 p.

Reid, R.P. and Tempelman-Kluit, D.J., 1987. Tethyan-type Upper Triassic reefs in Yukon. Bulletin of Canadian Petroleum Geology, vol. 35, no. 3, p. 316-332.

Senowbari-Daryan, B. and Reid, R.P., 1987. Upper Triassic sponges (Spinctozoa) from southern Yukon, Stikine Terrane. Canadian Journal of Earth Sciences, vol. 24, p. 882-902.

Stanley, G. D., Jr., 1994. Late Paleozoic and Early Mesozoic reef-building organisms and paleogeography: The Tethyan-North American connection. Cour. Forsch.-Inst. Senckenberg, vol. 172, p. 69-75.

Stanley, G. D., Jr. and Senowbari-Daryan, B., 1986. Upper Triassic, Dachstein-type, reef limestone from the Wallowa Mountains, Oregon: First reported occurrence in the United States. Palaios, vol. 1, p. 172-177.

Stanley, G.D., Jr. and Nelson, J.L., 1996. New investigations on Eaglenest Mountain, northern Quesnel Terrane: An Upper Triassic reef facies in the Takla Group, Central British Columbia (93N/11E). *In:* Geologic Fieldwork 1995, B. Grant and J.M. Newell (eds.). British Columbia Ministry of Energy, Mines, and Petroleum Resources, Geological Survey Branch, p. 127-135.

Tozer, E.T., 1958. Stratigraphy of the Lewes River Group (Triassic), central Laberge Area, Yukon Territory. Geological Survey of Canada, Bulletin 43, 28 p.

Westermann, G.E.G., Stanley, G.D., Jr., Yancey, T.E. and Newton, C.R., 1990. Paleogeography of the ancient Pacific. Science, vol. 249: p. 680-683.

Wheeler, J.O., 1961. Whitehorse map area, Yukon Territory. Geological Survey of Canada Memoir 312, 156 p.

Zankl, H., 1968. Sedimentological and biological characteristics of a Dachsteinkalk reef complex in the Upper Triassic of the Northern Calcareous Alps. *In:* Sedimentology Central Europe, G. Müller and G.M. Friedman (eds.). Springer, Berlin, p. 215-218.

Geology and geochemistry of the Clear Creek gold occurrences, Tombstone gold belt, central Yukon Territory

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Marsh, E.E., Hart, C.J.R., Goldfarb, R.J. and Allen, T.L., 1999. Geology and geochemistry of the Clear Creek gold occurrences, Tombstone gold belt, central Yukon Territory. *In:* Yukon Exploration and Geology 1998, C.F. Roots and D.S. Emond (eds.), Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 185-196.

ABSTRACT

Auriferous sheeted quartz veins and silicified shear zones occur along the margins and within adjacent hornfels zones of mid-Cretaceous Tombstone intrusions near the head of Clear Creek in the central Yukon. The lodes are the source for more than 120,000 ounces of downstream placer gold production. These lodes contain variable amounts pyrrhotite, pyrite, and arsenopyrite, with less abundant scheelite – alkali-feldspar, muscovite, biotite and tourmaline are common gangue phases. Grab samples of mineralization often contain gold grades in excess of 1 ounce per ton. Gold-to-silver ratios vary most commonly from 1:1 to 5:1. Gold-rich quartz veins cut all stocks, adjacent hornfels and associated lamprophyre dykes commonly contain greater than 1% arsenic. Bismuth, and less consistently tungsten and stibnite, characterize many of the most highly mineralized veins within and surrounding the stocks. Quartz veins along the intrusive-metasedimentary rock contact around the Pukelman stock are also enriched in lead and silver.

R-mode factor analysis of multi-element geochemical data for 111 gold- and sulphide-bearing rock samples indicates that there are two geochemically distinct metal suites in the Clear Creek occurrences. The first is characterized by As-Au-Bi ± Sb, Te ore-related mineral association, which is typical of many intrusion-related deposits in the Tombstone gold belt. Less consistently, anomalous concentrations of Ag, Co, Cu, Fe, and Mo occur within these auriferous rocks. The second metal factor is defined by Ag-Bi-Pb ± As, Au and Te. It characterizes metalliferous vein samples that have uncommonly low Au:Ag ratios and may represent a second hydrothermal episode. Tungsten shows little consistent correlation with the metalliferous veins in either element suite.

RÉSUMÉ

Des filons de quartz aurifère stratifiés et des zones de cisaillement silicifiées sont présents le long des bordures et dans les zones à cornéennes adjacentes de six amas intrusifs situés à proximité de la source du ruisseau Clear (115P/14). Ces amas font partie de la ceinture de Tombstone de 91Å0,5 Ma et leur composition va de la monzonite quartzifère à la diorite. Ils sont recoupés par des dykes d'aplite et de lamprophyre tardifs et pénètrent des roches clastiques du faciès des schistes verts inférieur à granulométrie fine du Groupe de Hyland d'âge s'échelonnant du Néo-protérozoïque au Cambrien précoce. Les plutons et les dykes se rencontrent de façon constante le long de structures d'extension orientées est-ouest.

Les filons et les zones de cisaillement minéralisées ont produit 120 000 oz d'or alluvionnaire en aval. Ces filons contiennent généralement de la pyrrhotite, de la pyrite, de la scheelite et de l'arsenopyrite en abondance. Les minéraux de gangue fréquents sont le feldspath potassique, la muscovite et la tourmaline. De nombreux indices minéralisés à forte teneur en or sont associés dans l'espace avec des cornéennes à forte teneur en biotite dans des roches clastiques, avec des zones de greisen dans des granitoïdes et avec de petites zones de skarn à tungstène dans des roches calcaires.

Les échantillons prélevés au hasard dans les filons et les zones silicifiées contiennent fréquemment des teneurs en or de plus d'un once la tonne (28 g/t). Les rapports or/argent de 1:1 à 5:1 sont typiques. Les résultats obtenus des analyses factorielles à mode R de données géochimiques montrent un cortège d'éléments Ag-As-Au-Bi-W cohérent apparenté au minerai et des anomalies d'antimoine et de plombe moins consistantes. Des filons de quartz aurifère recoupant tous les amas, les cornéennes limitrophes et les dykes de lamprophyre associés sont susceptibles de contenir plus de 1 % As. Les valeurs de bismuth et de tungstène de 100 à 1 000 ppm caractérisent les filons les plus fortement minéralisés situés à l'intérieur et à la périphérie des amas de Saddle, d'Eiger, de Josephine, de Pukelman et de Rhosgobel. Dans de nombreux échantillons, les enrichissements en antimoine varient entre 10 et 100 ppm. Les filons de quartz présents le long d'un contact de roches intrusives et métasédimentaires, sur le pourtour de l'amas de Pukelman, sont également enrichis en plomb; les échantillons titrent de 100 à 200 ppm Pb. La signature géochimique des filons du ruisseau Clear est cohérente avec celle du gisement de Fort Knox en Alaska et avec d'autres indices d'or situés dans la ceinture de Tombstone du Crétacé moyen.

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INTRODUCTION

A concentration of auriferous sheeted quartz veins and quartz stockworks are found in the Clear Creek area, about 120 km southeast of Dawson in west-central Yukon (Fig. 1). Except for a few small adits driven in the early 1900s, these lodes have not been mined but have been the focus of exploration activity for the past 20 years. These occurrences are the likely source for the more than 129,000 ounces (~ 4 million g) of gold that have been placer mined along Clear Creek since the turn of the century (Allen et al., this volume). Similarities in structural style, ore mineralogy, and spatial associations of the mineralization with several stocks of the Tombstone plutonic suite (~92 Ma) has led to their inclusion in the "Tombstone gold belt." This easterly-trending belt of intrusion-related gold deposits includes active gold mines at Fort Knox, Alaska (Bakke, 1995) and Brewery Creek (Diment, 1996), as well as the deposit at Dublin Gulch (Hitchins and Orssich, 1995; Smit et al., 1996; Maloof et al., 1997), 70 km northeast of Clear Creek.

Although there are regional studies of mineral occurrences (Emond and Lynch, 1990; Murphy, 1997), detailed studies of the geology and geochemistry of gold lodes in the Clear Creek area are unavailable. We initiated this study during the summer of 1998 to better understand the nature of mineralization and ore-forming fluids in the Tombstone gold belt. The portion of the study reported here is based upon detailed geochemical sampling of all the reported gold-bearing occurrences. We present results of multi-element metals analyses of mineralized samples from the numerous lode occurrences in the headwaters of Clear Creek. Data are subsequently interpreted statistically using R-mode factor analyses to better understand the correlation between elements and to define the geochemical signatures of the Clear Creek occurrences. Associated studies, including fluid inclusion geochemistry and stable isotope chemistry of the occurrences, and the radiogenic isotope character of the associated granitoids, are in progress.

SUMMARY OF GEOLOGICAL CHARACTERISTICS

The Clear Creek area is underlain by phyllite, quartzite, psammite, calc-phyllite, calc-silicate, grit and marble of the Yusezyu Formation of the Neoproterozoic to Early Cambrian Hyland Group (Murphy, 1997). The strata along the northern Selwyn Basin margin are imbricated by thrust faults of Jurassic and Early Cretaceous age. The Clear Creek area is in the hanging wall of the Robert Service Thrust within an east-trending, moderately north-dipping, transposed assemblage of lower greenschist facies rocks of the Tombstone Strain Zone (Murphy, 1997).

At the headwaters of Clear Creek, six Tombstone intrusions, the Saddle, Eiger, Pukelman, Rhosgobel, Josephine and Big Creek stocks, have surface exposures ranging from 0.2 to 3.5 km (Fig. 2). They yield U-Pb dates of ~92 Ma and are part of the Tombstone plutonic suite (Murphy, 1997). Notable gold occurs within and surrounding all except the Big Creek stock. The Saddle, Pukelman and Rhosgobel stocks are composed of medium- to coarse-grained quartz monzonite characterized by large (1cm) alkali feldspar phenocrysts. Local zones are granitic and aplitic, particularly in the southern Rhosgobel stock. Biotite is the dominant mafic mineral, but hornblende is not uncommon. The Josephine and Big Creek stocks are composed of fine- to medium-grained, equigranular granodiorite. The Eiger stock is composed of fine- to medium-grained, equigranular diorite with rare mafic phenocrysts. The intrusions have good exposure above treeline.

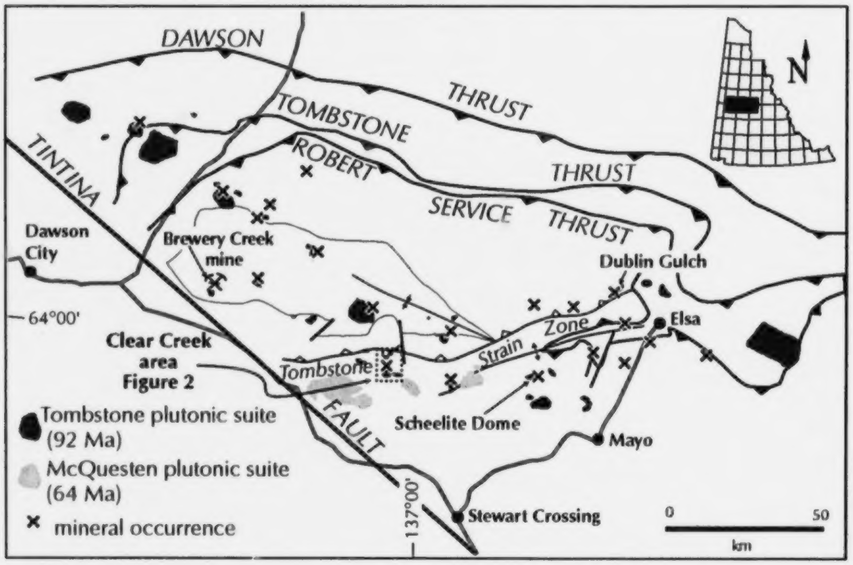

Figure 1. Geological framework of northern Selwyn Basin in west-central Yukon (modified from Murphy, 1997). The Clear Creek area (Fig. 2) is in the hanging wall of the Robert Service Thrust immediately south of the Tombstone Strain Zone.

Contact metamorphism of the Hyland Group country rocks extends for as much as 0.5 km around the stocks and is dominated by a resistant, rusty weathering biotite hornfels. Calcareous rocks are altered to calc-silicate and thin carbonate beds locally form small skarns.

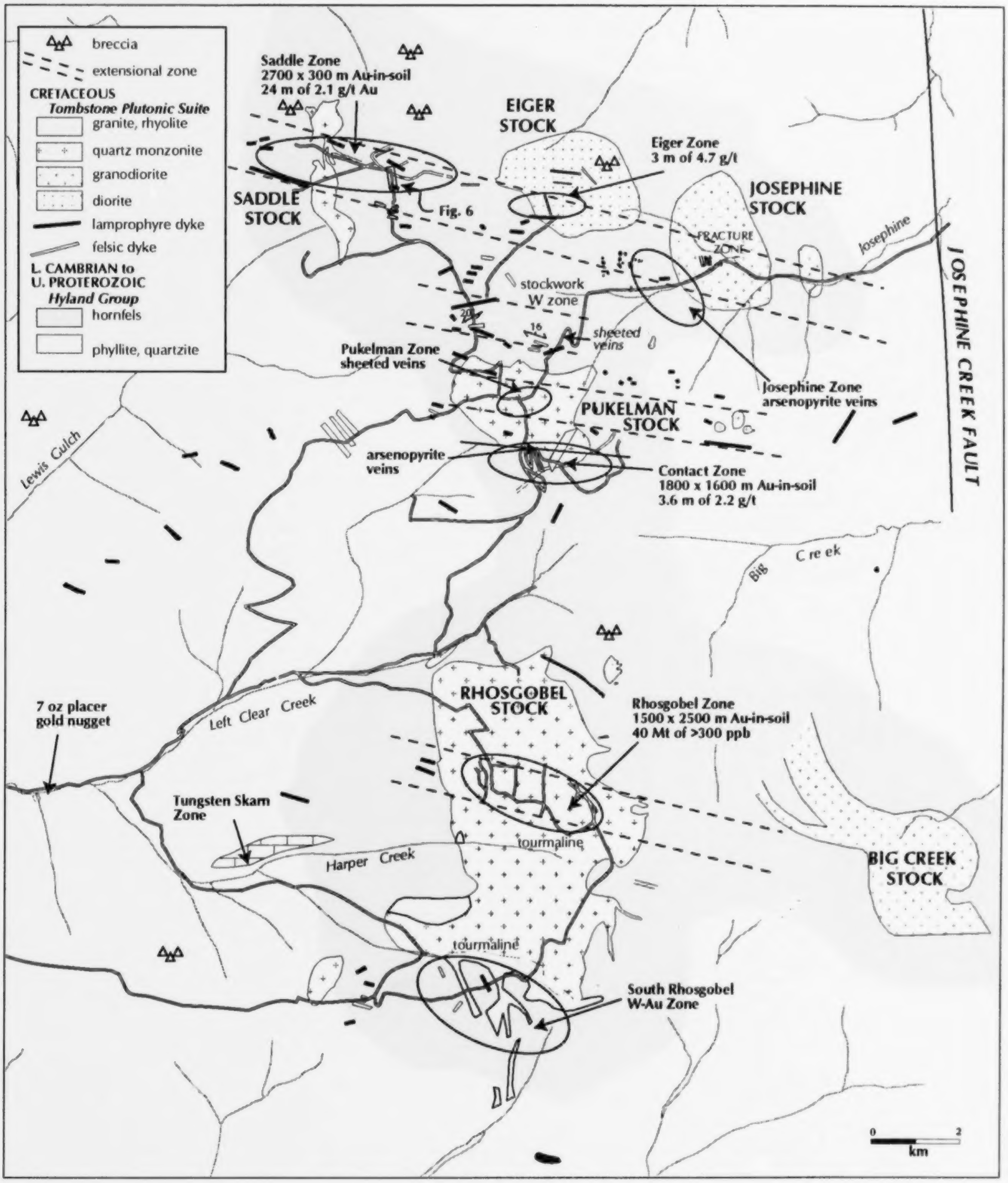
breccia
extensional zone
CRETACEOUS
Tombstone Plutonic Suite
granite, rhyolite
quartz monzonite
granodiorite
diorite
lamprophyre dyke
felsic dyke
L. CAMBRIAN to
U. PROTEROZOIC
Hyland Group
hornfels
phyllite, quartzite
Saddle Zone
2700 x 300 m Au-in-soil
24 m of 2.1 g/t Au
EIGER
STOCK
Eiger Zone
3 m of 4.7 g/t
JOSEPHINE
STOCK
SADDLE
STOCK
Fig. 6
FRACTURE
ZONE
Josephine
JOSEPHINE CREEK FAULT
stockwork
W zone
20
16
sheeted
veins
Pukelman Zone
sheeted veins
Josephine Zone
arsenopyrite veins
PUKELMAN
STOCK
Lewis Gulch
arsenopyrite
veins
Contact Zone
1800 x 1600 m Au-in-soil
3.6 m of 2.2 g/t
Big Creek
RHOSGOBEL
STOCK
7 oz placer
gold nugget
Left Clear Creek
Rhosgobel Zone
1500 x 2500 m Au-in-soil
40 Mt of >300 ppb
Tungsten Skarn
Zone
tourmaline
Harper Creek
BIG CREEK
STOCK
tourmaline
South Rhosgobel
W-Au Zone
0
2
km

Figure 2. *General geology of the upper Clear Creek drainage. Six stocks intrude Hyland Group metasedimentary rocks, each with a surrounding hornfels. All except the Big Creek stock are well mineralized. Linear regions, characterized by numerous parallel felsic and lamprophyre dykes, quartz and arsenopyrite veining, and alteration, are interpreted to represent zones of extension, delineated on this map by the dashed lines.*

Dykes, a common feature of the Clear Creek area, are dominantly ESE-trending and dip steeply (Fig. 3). Compositionally they are dominantly felsic, mostly composed of the porphyritic quartz monzonite. Also common are granite, quartz-feldspar porphyry, and rhyolite dykes. The felsic dykes are generally 0.5 to 2 m wide. Pegmatite and aplite dykes are thinner and are sparse outside of the intrusions. Lamprophyre dykes are up to 12 m wide, contain sparse biotite phenocrysts and biotite-diopside nodules, and cut all intrusive phases.

GOLD-BEARING MINERAL OCCURRENCES

Various styles of auriferous mineralization occur in the Clear Creek area, but intrusion-hosted sheeted arrays of low-sulphide quartz veins are predominant and characterize the Tombstone gold belt (Fig. 4). Irregularly spaced auriferous quartz veins are found in the adjacent hornfels. The sheeted and stockwork-style quartz veins, within the granitoids and hornfels, show traces to a few percent sulphide minerals, mainly arsenopyrite, pyrite, and less commonly, pyrrhotite. Scheelite is common in a minority of the veins and in local skarn zones. Molybdenite, galena, chalcopyrite, and bismuthinite have been also been reported (Coombes, 1997). K-feldspar, muscovite, biotite and carbonate are common gangue minerals, with less abundant tourmaline, albite and sericite.

Sheeted veins cut all intrusive rock types including felsic and lamprophyre dykes. Their localized coincidence with aplite and pegmatite dykes, and the presence of high-salinity fluid inclusions in metal-rich veins (Marsh, unpub. data), suggests a genetic link between mineralizing fluids and the latter phases of magma crystallization.

Arsenopyrite-rich veins are rare within the stocks but are normally in the margins or hosted by the hornfelsed country rocks. Notable occurrences occur on the margin of Josephine Creek stock in the Josephine Creek valley, and within the Contact zone at the southern margin of the Pukelman stock in the adjacent hornfels. Disseminated arsenopyrite is visible outside of some veins and within the most highly altered wall rocks.

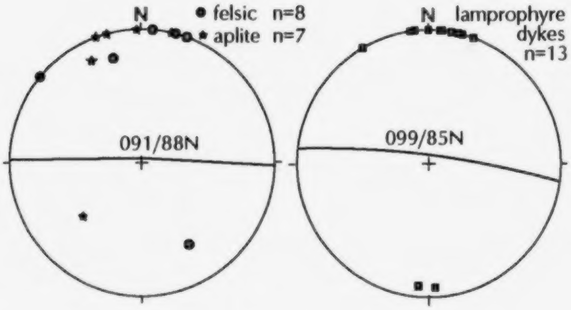

Figure 3. Equal-area, lower hemisphere projections of poles to planes of dykes measured in the Clear Creek area. Planes plotted are averages and may be shown steeper than actual since accurate dips were difficult to acquire.

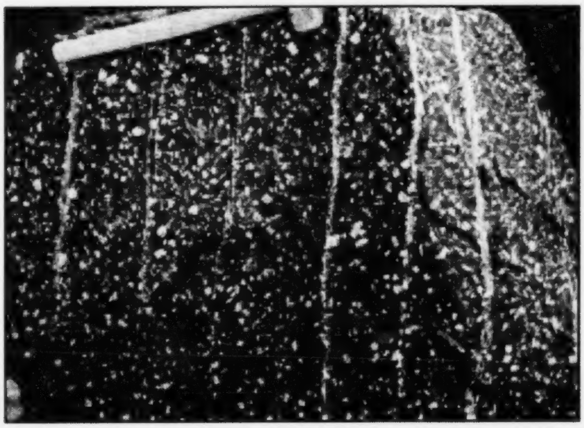

Figure 4. Sheeted quartz-muscovite-pyrite veins are characteristic of Tombstone Gold Belt mineralization. This example, from the central Pukelman stock, displays a particularly high density of veins. The porphyritic texture of the host quartz monzonite is also characteristic of the Saddle and Rhosgobel stocks. Hammer handle is 38 cm long.

Sheeted veins are in joints that are preferentially east-trending, within all of the stocks measured (Fig. 5). Other joint sets are rarely mineralized and cut the veins, thus indicating that the mineralized set represented the first set of dilational features. Veins not hosted in joints, sulphide-rich veins hosted in country rocks and felsic and lamprophyre dykes are also east-trending. Several east-trending zones that host numerous dykes and mineralized zones (i.e., Fig. 6) are continuous for several kilometres and likely represent extensional zones that evolved during waning magmatism.

GEOCHEMICAL METHODS

We collected 111 grab samples of quartz veins and stockworks, and of highly altered granitoid and hornfels throughout the headwaters of the Clear Creek. All analyses were performed by Chemex Labs Ltd. of North Vancouver, B.C. Samples were crushed in a ring-crusher to approximately minus-150 mesh. Gold was determined by standard fire assay on 30 g sample with atomic absorption (AA) finish; the lower determination limit was 5 ppb. Concentrations of 32 other major, minor, and trace elements in the 111 samples were determined by inductively-coupled plasma atomic emission spectroscopy

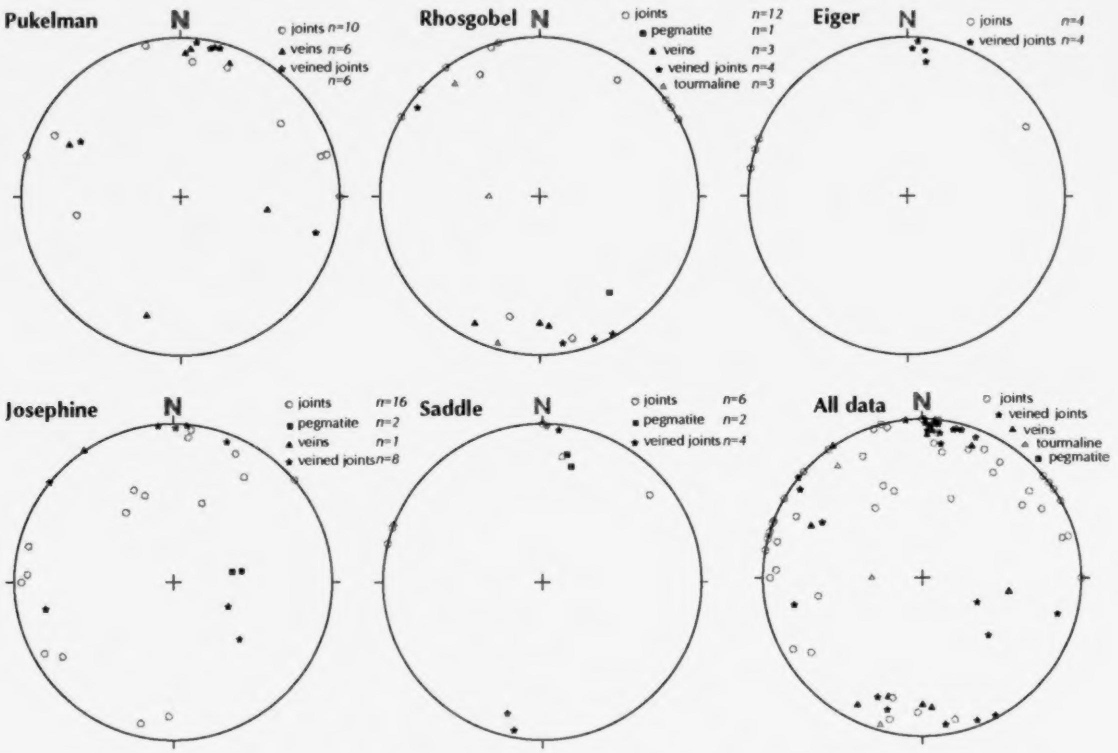

Figure 5. *Equal-area, lower hemisphere projection of joints and mineralized veins and pegmatites throughout the Clear Creek area. Data are plotted as poles to planes. Note the dominance of data from veins in joints near the North and South poles that indicate the east-trend of steeply dipping veins.*

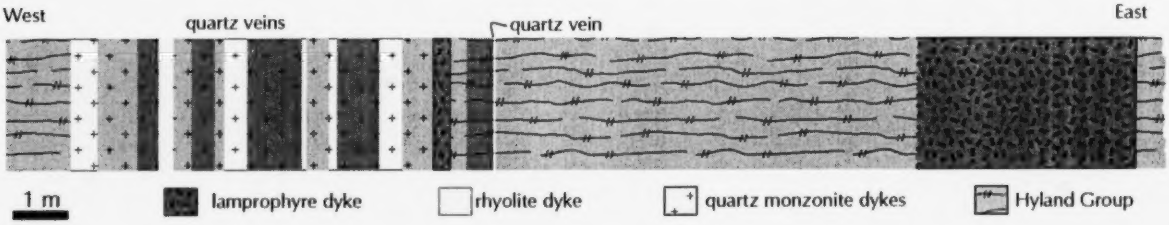

Figure 6. *Schematic section across the mineralized zone southeast of Saddle zone. Several felsic and two lamprophyre dykes, and numerous quartz ± arsenopyrite veins have infiltrated and altered the adjacent rocks. Alteration is denoted by shading with most altered rocks being darker.*

(ICP-AES) analysis using nitric-aqua regia digestion. Digestion was possibly incomplete for Al, Ba, Be, Ca, Cr, Ga, K, La, Mg, Sr, Ti, Tl, and W.

A few dozen samples with the highest gold concentrations were subsequently analyzed by AA methods for tellurium and selenium, subsequent to $HBr-Br_2$ digestion and $HCl-KClO_3$ digestion with organic extraction, respectively. Ten samples with notably high metal values were also analysed for tin using NH_4I sublimation and extraction with AA finish. None of these samples contained more than the lower determination limit of 2 ppm. Ten samples with anomalous tungsten values were reanalyzed by colorimetric analysis after potassium pyrosulfate fusion because of the possibility of incomplete digestion by the aqua regia leaching procedure used in the ICP-AS analysis. Tungsten values less than about 300 ppm were consistent between the two analytical methods. Differences at higher concentrations indicate that ICP-AS data for tungsten in Tables 1-5 must be viewed as only minimum approximations.

Resulting data for the Saddle area are presented in Table 1, Eiger stock areas in Table 2, Pukelman stock area in Table 3, Rhosgobel stock area in Table 4, and Josephine stock area and Josephine Creek in Table 5.

METALS GEOCHEMISTRY OF THE CLEAR CREEK GOLD OCCURRENCES

SADDLE AREA

The several constituents that make up the intrusions of the Saddle area include the Saddle stock, a range of dykes, and a monzonitic-granitic sill. The main porphyritic Saddle stock ranges in composition from monzonite to granite. The monzonite is a medium- to coarse-grained rock consisting of quartz, feldspar, biotite and minor hornblende with K-feldspar phenocrysts that can reach one centimetre in diameter (Coombes, 1996). The medium-grained equigranular granite consists of quartz, feldspar, biotite, and minor hornblende. Quartz veins cutting the intrusion contain as much as 3.9 ppm Au, 700 ppm As, 32 ppm Bi, 1.4 ppm Te, and 520 ppm W (sample 37). Altered monzonite and granite, with an abundance of secondary biotite, disseminated sulphides, and minor feldspar that is altered to sericite, occur adjacent to such veins. They contain as much as 2.8 ppm Au, 3.4 ppm Ag, 1965 ppm As, 46 ppm Bi, 1.4 ppm Te, and 170 ppm W (sample 36).

The stock is cut by several fine-grained lamprophyre dykes consisting mainly of fine-grained biotite and feldspar. A high density of arsenopyrite-rich quartz veins fill fractures in some of these lamprophyre dykes (Fig. 7). Alteration of the dykes within about 10 cm of the veins includes development of secondary biotite and arsenopyrite. Veins hosted by lamprophyre dykes (samples 7 and 9; Table 1) contain extremely high levels of Au (3.7-32 ppm), Ag (30-32 ppm), Bi (910-1455 ppm), and Sb (24-34 ppm); sample 9 also contained 875 ppm Cr, which is suggestive of inclusion of a chromite-bearing fragment from the dyke material. The Au:Ag ratios of ≤ 1, a relatively low arsenic content of sample 7, and concentrations of < 10 ppm W, contrast with the analyses of many other auriferous mineralized occurrences in the Clear Creek area, indicating probable local country rock control of elemental abundances of Ag, Bi, Sb, and W, for example. The vein cutting the dyke in sample 11 gives a

Table 1*. Mineralized samples from near the Saddle stock. (not/ss indicates insufficient sample for analysis)*

Sample and description

1 aplitic dyke with recrystallized biotite
2 quartz vein cut from sample 1
3 quartz vein with sulphide cut from aplite dyke
4 aplite dyke associated with vein of sample 3
5 biotite-rich recrystalized monzonite
6 monzonite with disseminated sulphides
7 quartz vein cut from lamprophyre dyke
8 lamprphyre dyke cut by quartz vein of sample 8
9 quartz vein with sulphide in lamprophyre dyke
10 porphyritic quartz monzonite
11 quartz vein from lamprophyre dyke
13 lamprophyre dyke
15 hydrothermally altered porphyry quartz monzonite
16 hydrothermally altered porphyry quartz monzonite
17 quartz vein cut from sample 17
18 hydrothermally altered porphyry quartz monzonite
19 quartz vein cut from sample 18
20 mafic intrusion rich in biotite, hornblende and quartz
21 biotite-rich vein in altered Hyland
22 porphyritic quartz monzonite
36 quartz monzonite with disseminated sulphides
37 quartz vein cut from 36
38 lamprophyre dyke
72 aplitic dyke with disseminated sulphides

Sample	1	2	3	4	5	6	7	8	9	10	11	13	15	16	17	18	19	20	21	22	36	37	38	72
Au ppb	<5	<5	>10,.000	4530	505	120	>10,000	85	not/ss	35	3230	20	1355	95	470	110	60	25	70	50	2850	3920	155	510
Ag ppm	<0.2	<0.2	3.2	0.8	<0.2	<0.2	32.2	0.2	30.4	<0.2	1.4	0.2	0.2	0.2	0.2	<0.2	<0.2	0.2	0.2	<0.2	3.4	0.2	<0.2	0.2
As ppm	99	50	630	1195	52	22	112	20	2310	68	>10,000	36	754	462	58	234	232	10	12	34	1965	704	60	8240
Ba ppm	70	30	160	130	170	560	40	360	10	290	10	1480	40	50	20	60	60	70	220	280	110	50	570	90
Bi ppm	<2	<2	226	50	2	6	910	6	1455	6	34	4	22	2	12	2	<2	<2	2	<2	46	32	<2	24
Co ppm	1	<1	4	6	14	15	3	8	6	3	30	22	1	<1	1	<1	<1	6	6	5	5	3	5	5
Cr ppm	56	197	136	89	100	102	356	57	875	67	288	244	82	63	220	103	147	95	193	74	148	211	32	63
Cu ppm	56	22	6	4	11	116	20	45	67	8	23	51	31	42	10	19	16	52	93	76	5	3	11	54
Fe %	1.28	0.47	0.89	2.14	4.34	5.38	0.9	3.08	1.86	1.52	2.77	3.55	1.1	0.64	0.36	0.47	0.56	1.2	3.59	2.59	1.23	0.75	4.18	2.34
La ppm	10	<10	10	30	40	130	<10	30	<10	50	<10	10	60	40	<10	60	30	20	40	50	40	30	40	10
Mg %	0.13	0.04	0.25	1.09	1.35	1.59	0.07	0.85	0.13	0.43	0.05	2.49	0.03	>0.01	0.01	0.01	0.02	0.32	0.71	0.69	0.46	0.24	1.06	0.14
Mn ppm	55	35	195	220	320	490	125	550	135	235	65	525	35	5	15	15	15	125	230	150	130	135	585	80
Mo ppm	1	4	1	1	<1	4	2	1	1	1	7	1	2	3	1	3	2	1	3	4	1	4	<1	2
Ni ppm	1	3	5	10	33	16	10	8	32	4	6	42	3	1	5	1	3	16	11	5	7	5	1	1
Pb ppm	14	14	8	10	6	8	24	8	42	8	12	10	12	16	6	16	10	12	8	6	26	6	12	10
Sb ppm	<2	<2	4	<2	<2	<2	34	<2	24	<2	30	<2	2	10	4	2	<2	<2	<2	<2	2	2	2	6
Te ppm			7.2	2.2	0.07						4.7		1		0.5	0.1					1.4	1.4		0.4
W (ICP) ppm	<10	<10	900	240	<10	20	<10	<10	<10	<10	100	<10	<10	<10	<10	<10	<10	90	10	10	170	520	20	<10
W (special)				160																	180	900		
Zn ppm	20	12	20	34	36	78	6	46	<2	42	20	88	10	2	2	2	<2	24	38	24	18	10	64	14

more typical geochemical signature (> 10,000 ppm As, 34 ppm Bi, 4.7 ppm Te, 100 ppm W) and a Au:Ag ratio > 1. Although containing visible disseminated arsenopyrite, the highly altered lamprophyre dyke samples were not notably enriched in gold (≤ 155 ppb Au) and other metals (samples 8, 13, and 38).

East of the Saddle Stock are several dykes that range in composition from aplite to lamprophyre. The aplite dykes are cut by several series of quartz veins. A vein with abundant scheelite, and the highest tungsten value from all the samples collected during this study (900 ppm; sample 3), contained > 10 ppm Au, 630 ppm As, 226 ppb Bi, and 7.2 ppm Te. The adjacent altered dyke, containing secondary biotite and abundant phenocrysts of arsenopyrite, has a similar signature although it contains lower concentrations for gold and all related pathfinder elements except arsenic. Another aplite dyke with a much higher concentration of disseminated arsenopyrite (sample 72), actually contained significantly lower concentrations of Au, Ag, Bi, Te, and W, despite a concentration of 8240 ppm As. This indicates that arsenic alone is not a consistently reliable pathfinder element for precious metal mineralization in the Clear Creek area.

A monzonitic to granitic sill, similar in composition and texture to the Saddle stock, outcrops ~200 m east of the stock. A series of quartz veins and a lamprophyre dyke cut the sill, with a selvage of secondary biotite and disseminated arsenopyrite around the veins for as much as 10 cm. Samples taken from the altered wall rock and a quartz vein contain as much as 3.9 ppm Au, 3.4 ppm Ag, 1,965 ppm As, 46 ppm Bi, 1.4 ppm Te, and 520 ppm W (samples 36 and 37, Table 1).

EIGER

The Eiger stock is an equigranular, fine- to medium-grained diorite with rare mafic phenocrysts. Gold mineralization occurs on the southern margin of the intrusion, within a zone along the contact with the Hyland Group country rocks. Several aplitic dykes, up to 2 metres in width, cut through this area. The adjacent diorite is often altered to flaky secondary biotite, irregularly silicified, and cut by sulphide-poor and arsenopyrite-

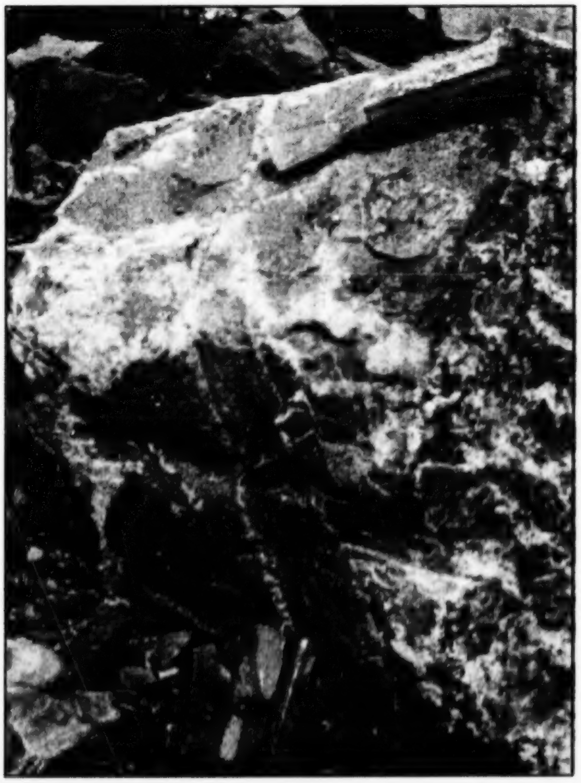

Figure 7. *Sheeted arsenopyrite-rich quartz veins (white) cutting a lamprophyre dyke (dark) in the Saddle area. Chisel near top is 21 cm long.*

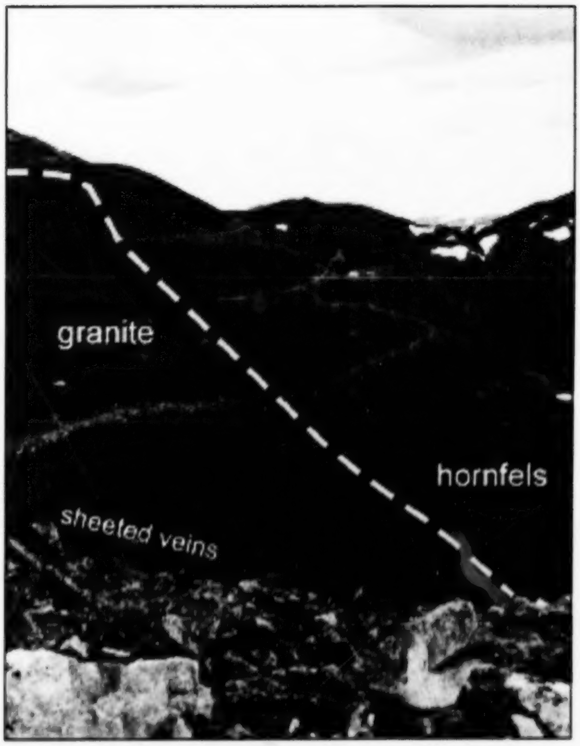

Figure 8. *View southeast towards the bulldozer roads workings and drill pads near the southern margin of the Pukelman stock (Contact zone). The top of the stock is exposed at left, with sheeted veins exposed in the felsemeer.*

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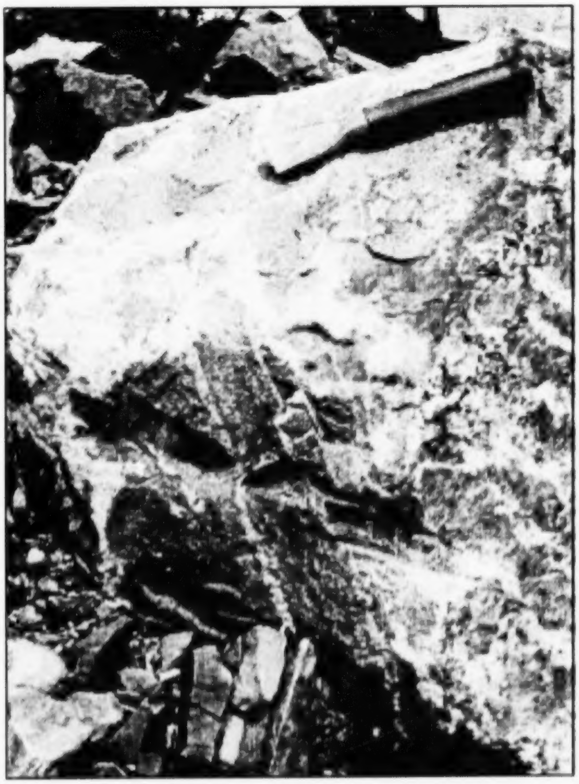

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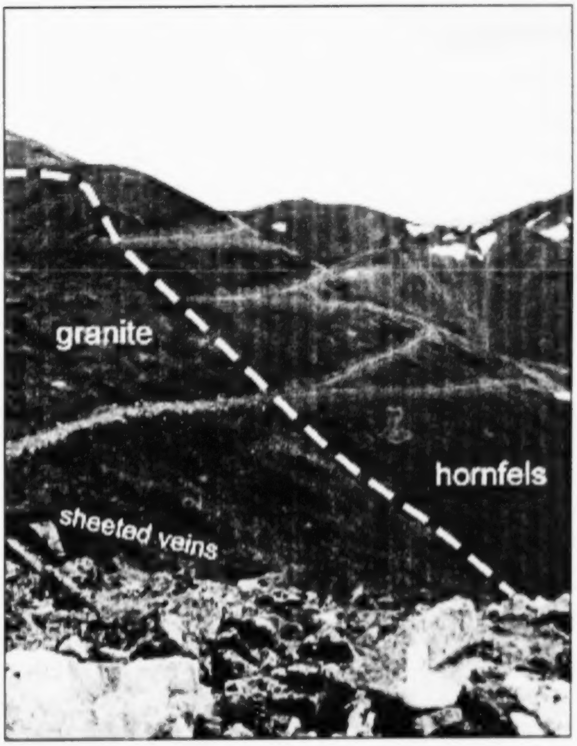

Figure 8. *View southeast towards the bulldozer roads workings and drill pads near the southern margin of the Pukelman stock (Contact zone). The top of the stock is exposed at left, with sheeted veins exposed in the felsemeer.*

rich quartz veins. Samples from the sulphide-rich veins contain about 3 ppm Au, and As, Bi and W contents of as much as > 10,000 ppm, 600 ppm, and 370 ppm, respectively (Table 2). Sulphide-poor veins are low in gold.

PUKELMAN

The Pukelman stock is a porphyritic monzonite that is similar to the Saddle stock. Mineralization occurs along the Contact zone at the margin of the intrusion and extends into the hornfels aureole (Fig. 8). This zone was the focus of previous exploration efforts that included diamond drilling. Medium- to fine-grained masses of biotite are abundant and may be part of a late-stage magmatic fluid event. Samples of these biotite-rich zones in the monzonite contain as much as 1.8 ppm Au, 5% Fe, 130 ppm W, and > 10,000 ppm respectively (sample 90). Many of the veins in Hyland Group rocks in the Contact zone are notable by their relatively high silver and lead contents. Talus fragments of milky white, arsenopyrite-bearing quartz veins in hornfels, contain 46 ppm Au, as well as 18 ppm Ag, 3840 ppm As, 16 ppm Bi, 300 ppm W and 38 ppm Pb (sample 91, Table 3). Sheeted quartz veins in the hornfels contain as much 116 ppm Au, 37 ppm Ag, > 10,000 ppm As, 546 ppm Bi, 206 ppm Pb, 54 ppm Sb, and 14 ppm Te (samples 99, 101, 103, and 104).

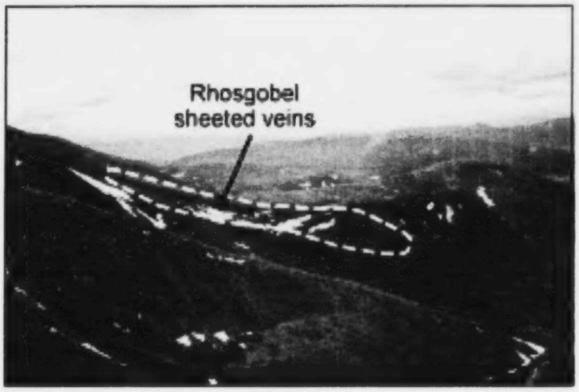

Figure 9*. View south towards the Rhosgobel Stock with the 1200 by 250 m region of >300 ppb Au in sheeted veins as outlined by drilling by Kennecott in 1995.*

RHOSGOBEL

The Rhosgobel stock is also a porphyritic monzonite comprising quartz, feldspar, biotite, and minor hornblende. Mineralization occurs as a series of sheeted quartz veins in the Rhosgobel stock within a 1.2 km-long ESE-trending zone (Fig. 9), and along its eastern contact. The veins consist of the quartz, stringers of tourmaline, and rare visible arsenopyrite crystals. Greatest precious metal concentrations in the veins cutting the intrusion are about 3.5 ppm Au, with gold-to-silver ratios of < 1. These veins also have low arsenic concentrations (< 40 ppm), 240-380 ppm W, and elevated lead values of as much as 84 ppm (samples 44 and 53; Table 4).

JOSEPHINE

The Josephine stock is a fine- to medium-grained granodiorite. Gold mineralization occurs as a series of transparent to milky, arsenopyrite-rich quartz veins that range from less than a millimetre to 13 cm wide. The veins intrude and alter granodiorite at the southeastern margin of the stock. Biotite is abundant, quartz and feldspar appear recrystallized, and minor garnet is present in altered areas. A sample of a quartz vein with abundant

Table 2*. Mineralized samples from near the Eiger stock. (not/ss indicates insufficient sample for analysis)*

Sample and description

58	aplitic dyke with disseminated sulphides
59	quartz vein cut from sample 58
60	quartz-enriched altered diorite
61	quartz vein cut from sample 60
62	diorite with disseminated sulphides
63	quartz vein cut from sample 62
64	altered diorite with recrystallized biotite
65	diorite with quartz enrichment
66	diorite
67	quartz bleb cut out of sample 66
68	arsenopyrite vein in diorite
69	quartz
70	arsenopyrite vein in diorite

Sample	58	59	60	61	62	63	64	65	66	67	68	69	70
Au ppb	20	145	90	95	25	95	<5	<5	<5	20	3290	135	not/ss
Ag ppm	0.2	0.2	<0.2	<0.2	<0.2	0.2	<0.2	<0.2	0.2	<0.2	1	<0.2	2.4
As ppm	102	92	44	212	50	66	72	66	32	56	>10,000	338	>10,000
Ba ppm	140	160	350	380	380	250	1140	700	470	60	150	30	10
Bi ppm	14	6	2	2	2	6	<2	<2	<2	<2	80	8	600
Co ppm	4	4	13	21	12	7	19	8	11	6	28	1	50
Cr ppm	112	380	97	268	162	229	114	60	205	408	89	347	22
Cu ppm	76	27	26	78	19	31	35	13	21	20	63	15	37
Fe %	1.7	0.97	3.48	3.99	2.86	2.4	4.8	2.78	3.08	1.04	5.16	0.49	>15.00
La ppm	40	20	30	30	10	30	50	30	10	<10	30	<10	<10
Mg %	0.49	0.24	1.49	1.59	1.65	1.42	2.59	0.76	1.59	0.28	1.32	0.01	0.02
Mn ppm	135	70	365	370	285	255	950	465	320	105	190	25	25
Mo ppm	<1	1	<1	7	<1	1	<1	<1	<1	1	1	1	5
Ni ppm	3	6	9	14	33	23	26	5	12	10	5	6	7
Pb ppm	12	6	12	12	10	8	8	6	12	2	10	6	50
Sb ppm	2	<2	<2	<2	<2	<2	<2	<2	2	<2	18	<2	274
Te ppm				0.1							1.1		
W (ICP) ppm	<10	<10	<10	190	<10	30	<10	<10	<10	<10	370	<10	20
W (special)					200						340		
Zn ppm	4	8	68	46	58	30	78	46	62	8	22	10	42

***Table 3**. Mineralized samples from near the Pukelman stock. (not/ss indicates insufficient sample for analysis)*

Sample and description

Sample	Description
88	biotite-rich altered quartz monzonite
89	biotite-rich altered quartz monzonite
90	biotite-rich altered quartz monzonite
91	quartz with arsenopyrite
92	quartz with arsenopyrite
93	biotite-rich seam through Hyland Group
94	quartz vein in altered Hyland Group with sulphides
95	biotite-rich quartz monzonite
96	quartzite with sulphides
97	Hyland quartzite
98	quartz vein from sample 97
99	quartz vein and sulphides in felsic Hyland
100	quartz vein and sulphides in felsic Hyland
101	quartz vein with tourmaline and sulphides
102	biotite-rich aplite
103	sulphide-rich quartz veins in Hyland quartzite
104	sulphide-rich quartz veins cut from 106
105	quartz and biotite veining in Hyland
106	Hyland quartzite
107	apalite with disseminated sulphides
108	quartz with sulphide
109	quartz with some Hyland
110	porphyritic quartz monzonite
111	quartz vein through felsic Hyland
112	quartz vein through felsic Hyland

Sample	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112
Au ppb	<5	<5	1845	>10,000	280	1805	210	255	965	225	625	8370	8310	>10,000	1015	not/ss	2850	340	50	80	1975	135	>5	40	65
Ag ppm	0.2	0.2	<0.2	18	<0.2	0.3	1.2	<0.2	<0.2	<0.2	<0.2	50.4	3.8	37.4	0.4	3.4	2.2	<0.2	<0.2	0.2	10.4	0.6	<0.2	<0.2	<0.2
As ppm	48	24	>10,000	3840	114	36	1740	212	6850	66	62	2440	368	>10,000	3690	6660	456	110	80	424	5010	388	38	18	46
Ba ppm	410	620	500	10	<10	140	<10	320	30	80	10	120	10	30	220	230	60	180	100	200	<10	40	260	<10	10
Bi ppm	<2	<2	6	16	<2	<2	8	2	<2	4	30	546	8	70	34	12	132	<2	2	<2	68	2	<2	2	<2
Co ppm	23	28	14	1	<1	9	1	13	4	1	1	5	1	13	13	4	1	9	1	<1	2	1	5	6	3
Cr ppm	194	279	93	263	354	248	511	79	227	301	285	279	416	375	136	503	375	250	313	112	247	309	123	226	350
Cu ppm	11	25	12	10	3	39	4	15	59	21	8	8	13	9	12	44	6	4	6	7	10	3	<1	4	4
Fe %	5.1	5.88	5.14	0.7	0.43	4.47	0.73	2.65	1.89	0.74	0.65	0.73	1.22	1.71	1.47	2.47	0.93	3.76	1.91	0.85	0.84	0.7	2.33	0.3	0.75
La ppm	20	20	50	<10	<10	30	<10	40	10	<10	<10	<10	30	<10	10	<10	10	40	10	10	<10	<10	30	<10	<10
Mg %	1.46	1.78	1.1	0.01	<0.01	1.21	<0.01	0.61	0.01	0.09	0.1	0.07	0.03	<0.01	0.45	0.03	0.16	1	0.53	0.06	<0.01	<0.01	0.6	0.01	0.2
Mn ppm	455	565	340	15	20	410	30	345	15	35	35	80	30	25	120	25	50	200	130	20	15	15	470	55	50
Mo ppm	<1	<1	2	1	1	<1	1	<1	<1	<1	1	7	1	2	3	3	1	6	<1	1	<1	6	1	1	1
Ni ppm	63	124	11	6	5	24	7	22	11	6	7	11	6	13	10	10	7	31	6	4	4	5	6	7	10
Pb ppm	10	10	6	38	<2	8	6	8	2	2	2	102	4	206	8	16	96	8	4	14	174	8	8	<2	<2
Sb ppm	2	<2	8	16	<2	<2	<2	<2	22	<2	<2	40	<2	54	<2	12	<2	<2	<2	<2	92	<2	<2	<2	<2
Te ppm			0.3	0.3		0.1			0.07			14	0.07	1.3	1.2	1.5	2.6				0.7				0.07
W (ICP) ppm	<10	<10	130	300	<10	<10	<10	20	<10	20	140	250	<10	<10	10	<10	<10	140	<10	<10	<10	<10	<10	10	680
W (special)				210																					700
Zn ppm	84	92	40	2	<2	76	<2	36	<2	2	2	6	6	2	16	2	6	44	18	16	2	<2	48	<2	2

***Table 4**. Mineralized samples from near the Rhosgobel stock. (not/ss indicates insufficient sample for analysis)*

Sample and description

Sample	Description
39	prophyritic quartz monzonite
40	quartz and tourmaline veins cut from sample 39
41	prophyritic quartz monzonite
42	quartz and tourmaline veins cut from sample 42
43	quartz and tourmaline vein
44	quartz vein with tourmaline veining cut from sample 45
45	prophyritic quartz monzonite with tourmaline and quartz
46	quartz vein with tourmaline and sulphides cut from sample 47
47	porphyritic quartz monzonite
48	quartz tourmaline and sulphide vein cut from sample 49
49	porphyritic quartz monzonite
50	quartz and tourmaline vein cut from sample 51
51	massive tourmaline
52	Hyland Group quartzite with quartz vein
53	sheeted quartz and tourmaline veins
54	clean porphyritic quartz monzonite
55	quartz and tourmaline in porphyritic quartz monzonite
56	pegmatitic muscovite, quartz, feldspar, and tourmaline

Sample	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56
Au ppb	425	80	10	<5	<5	3720	380	15	<5	<5	5	<5	<5	990	3520	15	<5	<5
Ag ppm	1	1.8	1	0.2	<0.2	32.2	4.4	7.6	1	0.6	0.6	0.2	<0.2	0.2	5.6	<0.2	0.2	0.2
As ppm	48	24	62	12	20	38	32	2	4	8	36	<2	2	2	16	6	40	10
Ba ppm	120	60	350	90	40	40	50	60	120	50	220	<10	<10	30	20	180	50	20
Bi ppm	12	6	<2	<2	<2	158	22	20	<2	8	2	<2	<2	16	146	<2	<2	<2
Co ppm	8	1	9	1	9	2	5	3	4	1	7	<1	<1	<1	1	5	4	1
Cr ppm	153	134	98	326	239	260	135	250	138	406	159	242	81	153	179	85	211	141
Cu ppm	8	3	13	6	10	6	18	5	9	3	8	3	2	4	3	2	3	6
Fe %	2.38	0.97	1.72	0.56	1.04	0.64	2.17	1	1.11	0.74	1.74	0.33	0.29	0.29	0.47	2.22	1.47	0.65
La ppm	40	20	40	<10	<10	<10	30	10	30	<10	40	<10	<10	<10	<10	30	10	<10
Mg %	0.07	0.04	0.06	0.03	<0.01	<0.01	0.03	0.04	0.08	0.06	0.14	0.04	0.09	0.03	0.01	0.59	0.02	<0.01
Mn ppm	210	75	2200	390	460	35	180	165	120	135	260	45	80	30	235	475	490	30
Mo ppm	13	4	1	<1	1	7	9	<1	<1	1	4	<1	<1	1	4	1	<1	1
Ni ppm	7	4	7	5	17	4	7	5	5	5	5	3	1	3	3	5	6	5
Pb ppm	64	38	24	6	2	84	74	72	24	26	48	10	8	12	42	12	30	28
Sb ppm	<2	<2	<2	<2	3	8	4	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Te ppm						4								0.8	5			
W (ICP) ppm	30	<10	20	<10	<10	240	10	<10	<10	<10	<10	<10	<10	10	380	<10	10	<10
W (special)						680									460			
Zn ppm	76	26	44	12	8	4	72	44	48	18	64	16	16	4	6	60	44	<2

Table 5. *Mineralized samples from near the Josephine stock.*

Sample and description

80 quartz vein with arsenopyrite
81 granodiorite
82 lamprophyre dyke
83 granodiorite with a quartz-feldspar-biotite vein
84 granodiorite with garnet and biotite
85 granodiorite with disseminated sulphide
86 granodiorite
87 quartz vein cut from sample 86

Sample	80	81	82	83	84	85	86	87
Au ppb	2390	25	<5	<5	<5	10	45	<5
Ag ppm	0.6	<0.2	0.2	<0.2	<0.2	<0.2	<0.2	1.4
As ppm	>10000	732	294	658	60	22	4240	88
Ba ppm	10	610	1190	630	880	770	800	460
Bi ppm	240	4	4	<2	<2	<2	20	<2
Co ppm	23	5	18	8	9	4	22	3
Cr ppm	249	158	321	132	164	93	156	264
Cu ppm	4	1	24	4	16	2	56	8
Fe %	7.08	2.68	4.03	2.73	3.25	2.38	3.78	1.54
La ppm	<10	30	10	40	40	40	30	20
Mg %	0.01	0.84	2.76	1.17	1.45	0.7	1.24	0.42
Mn ppm	25	325	540	310	395	265	280	135
Mo ppm	2	1	<1	<1	<1	<1	1	1
Ni ppm	4	5	20	11	15	4	11	7
Pb ppm	10	10	14	8	8	8	8	10
Sb ppm	52	<2	<2	<2	<2	<2	2	<2
Te ppm	0.9			0.07			0.07	
W (ICP) ppm	510	<10	<10	10	<10	<10	<10	<10
Zn ppm	12	48	70	66	94	46	38	20

arsenopyrite contains 2.4 ppm Au, > 10,000 ppm As, 240 ppm Bi, 7% Fe, 510 ppm W, and 52 ppm Sb (sample 80; Table 5).

FACTOR ANALYSIS OF LITHOGEOCHEMICAL DATA

R-mode factor analysis with Varimax rotation was used to identify the main element associations within the geochemical data. In factor analysis, similarly behaving variables (elements) are placed into groups termed factors. Specific rock types or ore deposit types are commonly represented by a distinct suite of trace elements, and therefore certain factors may indicate these common geochemical signatures. Factor loadings, which depict the influence of each variable on a factor, may be interpreted similarly to correlation coefficients.

Since some data range beyond the limits of the analytical techniques, several corrections are necessary for their incorporation into the statistical method. All data qualified with a "less than" value were replaced with 0.7 times the lower determination limit prior to calculations. Data qualified by "greater than" were replaced with 1.3 times the upper determination limit. Four samples that had insufficient material for gold analysis, were given gold values of three times the silver concentration (an approximate average Au:Ag ratio for the mineralized veins in the Clear Creek area). The highly censored (data qualified with > or <) elements consisting of Cd (all values ≤ 0.5 ppm), Ga (all values ≤ 10 ppm), Hg (all values < 1 ppm), Sb (most values < 2 ppm), Tl (all values < 10 ppm), U (all values ≤ 10 ppm), and W (most values ≤ 10 ppm) were eliminated from analysis. Data for Te and Se were not included because these elements were only determined for a select suite. All raw data for the remaining 24 elements were converted to logs and then run through factor analysis using Statistica 5.0 (StatSoft Inc., 1995). A five-factor model that explains about 79% of the total variance was selected as the most appropriate for summarizing the geochemical associations in the data from the Clear Creek area (Table 6). The factors are discussed below.

The first factor contains high loadings for Al, Ba, Ca, Fe, K, Mg, Mn, Na, P, Sc, V, and Zn. This signature represents relatively unmineralized intrusive and country rocks. These samples were analysed as they represented variably altered wall rock adjacent to sulphide-bearing veins. These elements are typical of common rock-forming silicate and carbonate minerals in both the hornfels zones and granitoid stocks. If a sample of country rock was significantly mineralized by the gold-forming event, then it would not have a high score in factor one; but would be better defined by factors 2 or 4 (see below).

Table 6. *Five-factor model of R-factor analysis of geochemical associations in the Clear Creek area. Factors 1 and 2 describe metallogenic associations, whereas factors 3, 4 and 5 describe lithologic associations. Additional characterizations are explained in text. Positive numbers indicate the degree of positive correlation.*

Element	1	2	3	4	5
Au		0.80		0.36	
Ag	-0.26	0.31		0.84	
Al	0.88				
As		0.87			
Ba	0.88				
Be	0.34	-0.30			0.65
Bi		0.57		0.69	
Ca	0.85				
Co	0.64	0.26	0.53		
Cr	-0.48		0.63		-0.29
Cu	0.27	0.42	0.30		0.29
Fe	0.71	0.30	0.36		0.25
K	0.85				
La	0.63				0.52
Mg	0.93				
Mn	0.76	-0.39	0.25		
Mo		0.27			0.54
Na	0.85				
Ni	0.32		0.88		
P	0.82				0.33
Pb				0.84	
Sc	0.88				
Sr	0.90				
Ti	0.89			-0.25	
V	0.91				
Zn	0.80				0.27
Cumulative %	47.63	60.84	68.67	74.23	78.52

Factors 3 and 5 represent lithologic associations within the rock data. Samples with highest scores onto factor 3, a factor with highest loadings for Ni, Co, Cr, Fe ± Cu and Mn; these samples were collected from mafic rocks in the Clear Creek area. Most of these samples are lamprophyre dykes from the Saddle area, Eiger stock, and Josephine stock. Factor 5 is characterized by an element association of Be, La, Mo and P; highest scores were samples collected from the Rhosgobel and Pukelman stocks. These granitoids may be slightly more evolved than the other three stocks in the study area.

Factors 2 and 4 represent the precious metal mineralization assemblage in the Clear Creek area. Factor 2 (13% of the overall data variance), is defined by very high loadings for Au, As, and Bi, with less significant values for Ag, Co, Cu, Fe, and Mo. The samples with high scores were collected from quartz veins in the lamprophyre dykes cutting the Saddle stock and surrounding Hyland Group hornfels; quartz veins in the Saddle area trench; quartz veins and alteration zones in the Saddle area sill; biotite-rich, highly-altered rocks in the Pukelman contact zone; and sheeted quartz veins cutting the Josephine stock. This suggests that arsenopyrite- and Bi-bearing mineral phases are most closely associated with gold in the Clear Creek area. In addition, many of the samples with the highest scores also had high Sb and Te concentrations. It is therefore likely that Bi- and Au-bearing tellurides are common in many veins; the anomalous antimony, typically < 100 ppm, is probably present in arsenopyrite. Tungsten, not included in the factor analysis, is enriched in some samples with high factor 2 scores (e.g., samples 4, 11, 68, 90, 91), but typically shows little association with the gold-bearing suite (e.g., samples 33, 37, 61, 98, 105, 112).

Factor 4, in contrast to factor 2, is dominated by silver and lead, with bismuth and irregular As loadings. Gold has a weaker positive loading than in factor 2. High scores for this factor (samples 3, 9, 44-46, 53, 77, 78, 99, 101, 108) were collected from arsenopyrite-rich veins in the Eiger stock; some quartz veins in the lamprophyre dykes of the Saddle area; quartz in talus with arsenopyrite from the Pukelman Contact zone; sheeted quartz veins cutting the hornfels and quartzite of the Hyland Group surrounding the Pukelman stock; and sheeted veins hosted by the Rhosgobel stock. This factor indicates metalliferous locations characterized by Ag>Au and lead values typically 40-200 ppm, suggesting local argentiferous galena. Critical factor 2 elements such as gold (e.g., samples 45, 46, 77, 78) and arsenic (e.g., samples 44-46, 53, 77-78), are often at background levels in Factor 4. Bismuth and tellurium are consistently elevated in samples with the highest silver and lead concentrations, suggesting a complex, but not necessarily gold-rich, metal assemblage.

DISCUSSION

Gold-bearing veins are most apparent in Hyland Group rocks surrounding the Pukelman stock; in lamprophyre dykes and, less commonly, in aplitic dykes, of the Saddle area; and in arsenopyrite-rich zones along the margin of the Eiger stock. Less extensive and lower grade occurrences are located near the margins of the Josephine, Rhosgobel, and Pukelman stocks. The spatial distribution of the lodes indicates that the more favourable occurrences may be coincident with late-stage dykes and sills, and in the hornfels.

Results from factor analysis indicate that the gold-rich zones are characterized by a consistent As-Au-Bi signature. Emond and Lynch (1990) indicated that many of the veins in this part of the Yukon contained anomalous bismuth, but that a correlation between bismuth and gold was not apparent. Our detailed sampling in the Clear Creek area indicates a strong positive correlation between gold and bismuth and supports similar assertions by Murphy et al. (1993). Gold-bismuth correlations in other deposits of the Tombstone gold belt have also been documented by Bakke, (1995); Hitchins and Orssich, (1995); and McCoy et al., (1997).

Tellurium and antimony locally occur at elevated values in gold- and bismuth-enriched samples containing visible pyrite and arsenopyrite. Although these elements are too highly censored for inclusion in the factor analysis, they appear to be additional important pathfinder elements for the gold occurrences in the Clear Creek area.

Therefore, any soil or rock geochemical exploration program for gold ores in the Clear Creek area should consider As, Au, Bi, Sb, and Te as the elements that would be most useful for the identification of localities proximal to significant gold-bearing lode occurrences.

CONCLUSIONS

Auriferous sheeted quartz veins and silicified shear zones occur along the margins and within adjacent hornfels zones of five stocks of the Tombstone plutonic suite near the head of Clear Creek. Sheeted veins cut all intrusive rock types including felsic and lamprophyre dykes. Sheeted and solitary veins in the intrusions and hornfels, as well as felsic and lamprophyre dykes are all dominantly east-trending. Zones with high vein and dyke densities are interpreted as localities of extension.

The lodes typically contain variable amounts pyrrhotite, pyrite, and arsenopyrite, with scheelite sporadically abundant. Alkali-feldspar, muscovite, biotite and tourmaline are common gangue phases. Many of the gold-rich mineral occurrences are in biotite-rich hornfels.

Grab samples of mineralized rock locally contain gold grades in excess of 1 ounce per ton. The gold-rich samples typically contain greater than 1% arsenic. Bismuth, and less consistently tungsten values of 100-1000 ppm characterize many of the most highly mineralized veins within and surrounding the stocks.

Quartz veins along the intrusive-metasedimentary rock contact around the Pukelman stock are also enriched in lead and silver, with samples containing 100-200 ppm Pb and 18-37 ppm Ag.

In many of these samples, antimony enrichments range between 10-100 ppm.

R-mode factor analysis of multi-element geochemical data discern a five-factor model that explains 79% of the total variance. Three factors define the geochemical signatures of the main lithologies. The suites reflect (1) common rock-forming silicate and carbonate minerals of the Hyland Group and typical granitoids, (2) mafic silicate phases in the lamprophyre dykes and (3) incompatible elemental enrichments in the most evolved granitoid phases. Sulphide-bearing quartz veins and hydrothermally altered wall rocks are represented by the two other factors. The first of these is the As-Au-Bi ± Sb, Te ore-related mineral association characteristic of intrusion-related gold deposits throughout the Tombstone gold belt. Less consistently, anomalous concentrations of Ag, Co, Cu, Fe, and Mo occur within these auriferous rocks. The second metal suite noted from the factor analysis is defined by Ag-Bi-Pb ± As, Au, Te and characterizes metalliferous vein samples that have uncommonly low Au:Ag ratios. The geochemical signature particularly characterizes many samples from in and around the Pukelman stock. It may identify a second metalliferous hydrothermal event in the Clear Creek area. Tungsten shows little consistent correlation with the metalliferous rocks in either element suite.

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REFERENCES

Allen, T.L., Hart, C.J.R. and Marsh, E.E., 1999. Placer gold and associated heavy minerals of the Clear Creek drainage, central Yukon: past to present. *In:* Yukon Exploration and Geology 1998, C.F. Roots and D.S. Emond (eds.), Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 197-214.

Bakke, A.A., 1995. The Fort Knox "porphyry" gold deposit – Structurally controlled stockwork and shear quartz vein, sulphide-poor mineralization hosted by a Late Cretaceous pluton, east-central Alaska. *In:* T. A. Shoeter (ed), Porphyry Deposits of Northwestern Cordillera of North America. Canadian Institute of Mining and Metallurgy, Special vol. 46, p. 795-802.

Coombes, S., 1996. 1995 Exploration report on the Clear Creek option, Yukon Territory. Kennecott Canada Inc. Mineral Resources Division, Indian and Northern Affairs Canada, Yukon Assessment Report, 39 p.

Diment, R., 1996. Brewery Creek gold deposit, central Yukon. *In:* Yukon Exploration and Geology 1995, Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 57-66.

Emond, D.S. and Lynch, T., 1990. Geology, mineralogy and geochemistry of tin and tungsten veins, breccias and skarns, McQuesten River region (115P (north) and 105M/13), Yukon. *In:* Yukon Geology Vol. 3, Indian and Northern Affairs, Yukon, Exploration and Geological Services Division, p. 133-159.

Hitchins, A.C. and Orssich, C.N., 1995. The Eagle zone gold-tungsten sheeted vein porphyry deposit and related mineralization, Dublin Gulch, Yukon Territory. *In:* T.A. Schroeter (ed), Porphyry Deposits of the northwestern Cordillera of North America. Canadian Institute of Mining and Metallurgy, Special vol. 46, p. 803-810.

Maloof, T.L., Thompson, J.F.H. and Smit, H., 1995. The Eagle zone sheeted vein Au deposit and related mineralization at Dublin Gulch, central Yukon. Geological Association of Canada, Annual meeting, Abstracts with Program, vol. 20, p. A97.

McCoy, D., Newberry, R.J., Layer, P., DiMarchi, J.J., Bakke, A., Masterson, J.S. and Minehane, D.L., 1997. Plutonic related gold deposits of interior Alaska. *In:* Mineral Deposits of Alaska, R.J. Goldfarb and L. Miller (eds), Economic Geology Monograph 9, p. 191-241.

Mortensen, J.K., Murphy, D.C., Poulsen, K.H. and Bremner, T., 1996. Intrusion-related gold and base metal mineralization associated with Early Cretaceous Tombstone Plutonic Suite, Yukon, and east-central Alaska. Notes for short course on Mineral deposits models of the Cordillera, British Columbia Geological Survey, 1996 Cordilleran Roundup, B.C. and Yukon Chamber of Mines, Vancouver, B.C.

Murphy, D.C., 1997, Geology of the McQuesten River region, northern McQuesten and Mayo map areas, Yukon Territory (115P/14, 15, 16; 105M/13, 14). Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, Bulletin 6, 122 p.

Murphy, D.C., Héon, D. and Hunt, J., 1993. Geological overview of Clear Creek map area, western Selwyn Basin (NTS 115P/14). *In:* Yukon Exploration and Geology 1992. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 61-69.

Smit, H., Sieb, M. and Swanson, C., 1996. Summary information on the Dublin Gulch project, Yukon Territory. *In:* Yukon Exploration and Geology 1995. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 33-36.

StatSoft Inc., 1995. Statistica 5.0. Tulsa, OK.

Yukon Minfile. Exploration and Geological Services Division, Yukon. Also available from Hyperborean Productions, Whitehorse, Yukon.

Placer gold and associated heavy minerals of the Clear Creek drainage, central Yukon: Past to present

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ABSTRACT

Placer gold mining in Clear Creek extends back to 1900, when the discovery claim was staked. Approximately 129,000 crude ounces (4012 kg) of gold have been reported since 1941 which includes 49,637 crude ounces (1544 kg) obtained by dredging operations (1941 to 1955, and 1981 to 1987). Placer gold morphology ranges from crystalline gold in quartz to rounded nuggets to flattened gold. The largest nugget, recovered from the headwaters of Left Clear Creek, weighed 7 ounces (218 g).

Clear Creek valley was filled by ice during the pre-Reid glaciation (early Pleistocene). Pre-Reid glacial drift is preserved as till, resedimented till, and glaciofluvial sediments on the lower slopes along main Clear Creek and parts of Left Clear Creek. Alpine glaciers formed at the headwaters of Left Clear Creek, however most of the moraine deposits have been eroded. During the subsequent Reid and McConnell glacial periods local alpine glaciers formed in the headwaters of Josephine and Big creeks. Alpine glaciers, the pre-Reid ice sheet and their melt waters redistributed the gold in the Clear Creek drainage.

The distribution of heavy minerals in Clear Creek drainage is varied. Over the years dredging operations intersected pockets of gravel containing cassiterite, scheelite and galena, but their precise locations were not documented. Contemporary placer mining and our heavy mineral studies have located concentrations of pyrite, arsenopyrite, scheelite and galena, in addition to gold. Exploration for the source of placer gold has resulted in the discovery of numerous gold veins in the surrounding area.

RÉSUMÉ

L'exploitation de placers aurifères au ruisseau Clear remonte aux années 1900 alors que fut jalonné le claim de la découverte. On a signalé depuis 1941 l'extraction d'environ 129 000 onces d'or brut (4012 kg), ce qui inclut 49 637 onces d'or brut récupérés par dragage (de 1941 à 1955 et de 1981 à 1987). L'or placérien récupéré au ruisseau Clear présente une morphologie variant de l'or cristallin dans le quartz à des pépites d'or aplaties à arrondies. La plus grosse pépite pesait 7 onces (218 g) et fut récupérée sur le cours supérieur du ruisseau Left Clear.

La vallée du ruisseau Clear a été comblée par la glace durant la glaciation de pré-Reid (Pléistocène inférieur). Les dépôts glaciaires pré-Reid sont conservés sous forme de till, de till redéposé et de sédiments fluvioglaciaires sur le bas des pentes le long du ruisseau Clear principal ainsi que sur des parties du ruisseau Left Clear. Des glaciers alpins se sont formés sur le cours supérieur du ruisseau Left Clear, mais la plupart des dépôts morainiques ont été érodés. Pendant les périodes glaciaires ultérieures de Reid et de McConnell, des glaciers alpins locaux se sont formés sur le cours supérieur des ruisseaux Josephine et Big. Les glaciers alpins, la nappe glaciaire pré-Reid et leurs eaux de fonte ont redistribué l'or dans le bassin versant du ruisseau Clear.

La répartition des minéraux lourds dans le bassin versant du ruisseau Clear est variable. Au fil des ans, les travaux de dragage ont recoupé des poches de gravier contenant de la cassitérite, de la scheelite et de la galène, mais les positions précises de ces amas n'ont pas été relevées. Les travaux contemporains d'exploitation de placers aurifères et nos études des minéraux lourds ont permis de localiser des concentrations de pyrite, d'arsénopyrite, de scheelite et de galène en plus de l'or. L'exploration visant la recherche de(s) la source(s) de l'or placérien a permis la découverte de nombreux filons aurifères dans les environs.

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INTRODUCTION

Placer gold has been mined from the Clear Creek drainage episodically since 1900. The history of placer mining in the Clear Creek drainage, as well as the total gold production, is poorly documented. We present a compilation of the historical development of placer mining in the Clear Creek drainage and present data that document the recovery of more than 129,000 crude ounces (4012 kg) of placer gold.

The origin of gold-bearing gravel deposits is poorly understood. We compiled the glacial and depositional history of the region and present new sedimentological sections and data that indicates a largely fluvial origin for gold-bearing gravel in the valley of the Clear Creek drainage, overlain by organic-rich silt and sand ("muck").

The hard rock source(s) of placer gold have intrigued explorationists for decades. Although some lode gold occurrences have been recognized in the region, they are typically low-grade or the gold grains are very small. This is in sharp contrast to coarse placer nuggets weighing up to 7 oz (218 g) that have been recovered from creek gravels. The goal of this study is to better constrain potential lode sources of the placer gold in the Clear Creek area by examining the characteristics of the gold (including fineness[1]) and the associated heavy mineral suite. A total of 29 samples of panned heavy minerals were collected from many of the tributaries to Clear Creek (Fig. 1).

PREVIOUS WORK

Previous studies of the surficial geology in the Clear Creek drainage were carried out by Bostock (1966) and Hughes et al. (1969), who both noted that Clear Creek is beyond the Reid and McConnell glacial limits of the Cordilleran ice sheet. More recently, Morison (1983a; 1984) undertook a sedimentological study of the Clear Creek surface deposits. Even more recently,

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[1] Fineness, expressed in parts per thousand, is defined as the ratio of gold to gold plus silver, multiplied by 1000 (Au/(Au+Ag)x1000) (Boyle, 1979).

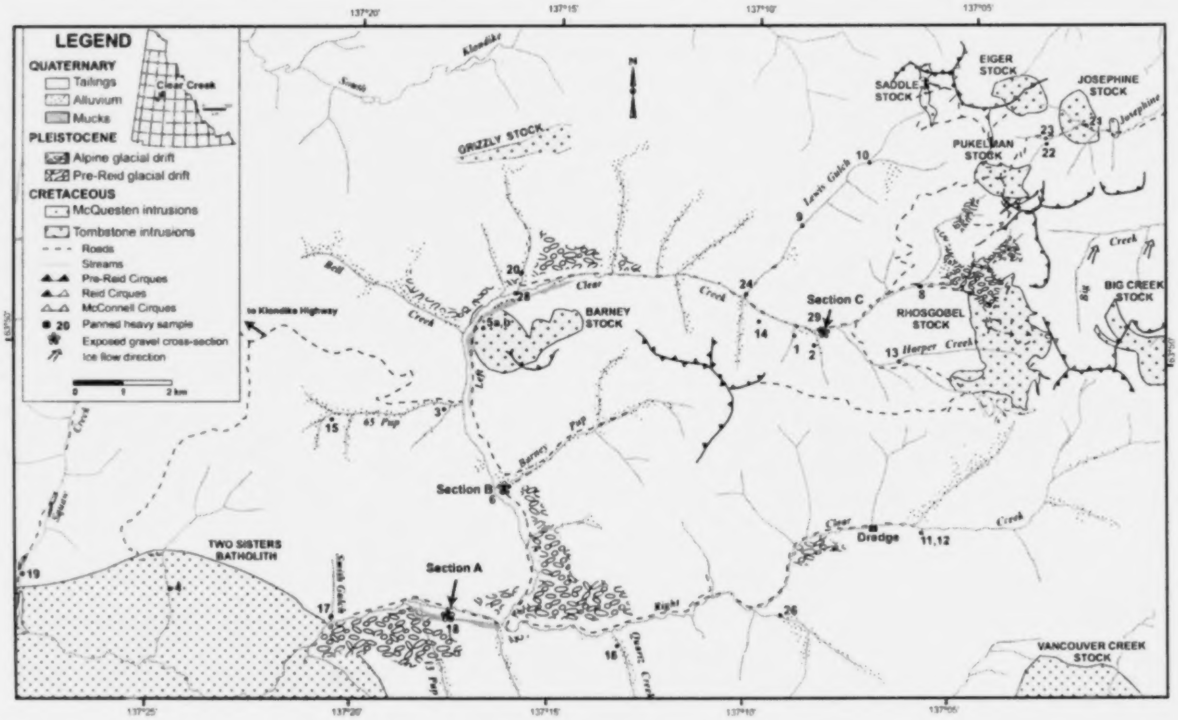
LEGEND
QUATERNARY
Tailings
Alluvium
Mucks
PLEISTOCENE
Alpine glacial drift
Pre-Reid glacial drift
CRETACEOUS
McQuesten intrusions
Tombstone intrusions
Roads
Streams
Pre-Reid Cirques
Reid Cirques
McConnell Cirques
20 Panned heavy sample
Exposed gravel cross-section
Ice flow direction
0 1 2 km
Clear Creek
137°20'
137°15'
137°10'
137°05'
137°25'
N
Klondike
GRIZZLY STOCK
EIGER STOCK
SADDLE STOCK
JOSEPHINE STOCK
Josephine
PUKELMAN STOCK
BARNEY STOCK
RHOSGOBEL STOCK
BIG CREEK STOCK
TWO SISTERS BATHOLITH
VANCOUVER CREEK STOCK
to Klondike Highway
Section A
Section B
Section C
Lewis Gulch
Bell Creek
Clear Creek
Harper Creek
65 Pup
Barney Pup
Left Clear Creek
Right Clear Creek
Quartz Creek
Smith Gulch
Big Creek
Dredge
10
9
20
28
5a,b
24
29
14
1
2
8
13
23
21
22
15
3
6
19
4
17
18
16
26
11,12

Figure 1. Compilation of major surficial and bedrock geological features and locations of panned heavy samples from Clear Creek drainage. Geology modified from Murphy et al. (1996) and various assessment reports. Areas defining alluvium, alpine and pre-Reid glacial drift from (Morison, 1983b). The location and approximate age of cirques (alpine glaciers) illustrated on this map were interpreted from air photos for this study to determine the effects of local glaciation.

Bond and Duk-Rodkin (in progress) conducted surficial mapping (1:250 000 scale) of the McQuesten region, including indications of meltwater flow in the Clear Creek drainage.

Regional bedrock geological maps (1:250 000 scale) of the area have been produced by Bostock (1964), but the region benefits from recent detailed geological mapping (1: 50 000 scale) (Murphy et al., 1996) and an accompanying summary report (Murphy, 1997). Hard rock exploration in the Clear Creek region has been documented since 1902 (Yukon Minfile), but has been particularly active for over the last 20 years, including Bema Resources Ltd. from 1979 to 1982, Gold Rite Mining Co. from 1987 to 1988, Ivanhoe Goldfields Ltd. in 1994, and Kennecott from 1995 to 1996. Detailed descriptions of veins and skarns (Rhosgobel, Josephine, Lewis, and Pukelman), that occur at the headwaters of Clear Creek (Fig. 2), and their associated mineralization were presented by Emond (1986, 1989) and Emond and Lynch (1990).

PREVIOUS MINING ACTIVITY

Since 1900, the Clear Creek drainage has had a long and varied history of placer mining including hand workings, hydraulicking, draglines, two periods of dredging, and contemporary heavy machinery. Mining has been sporadically active at various locations

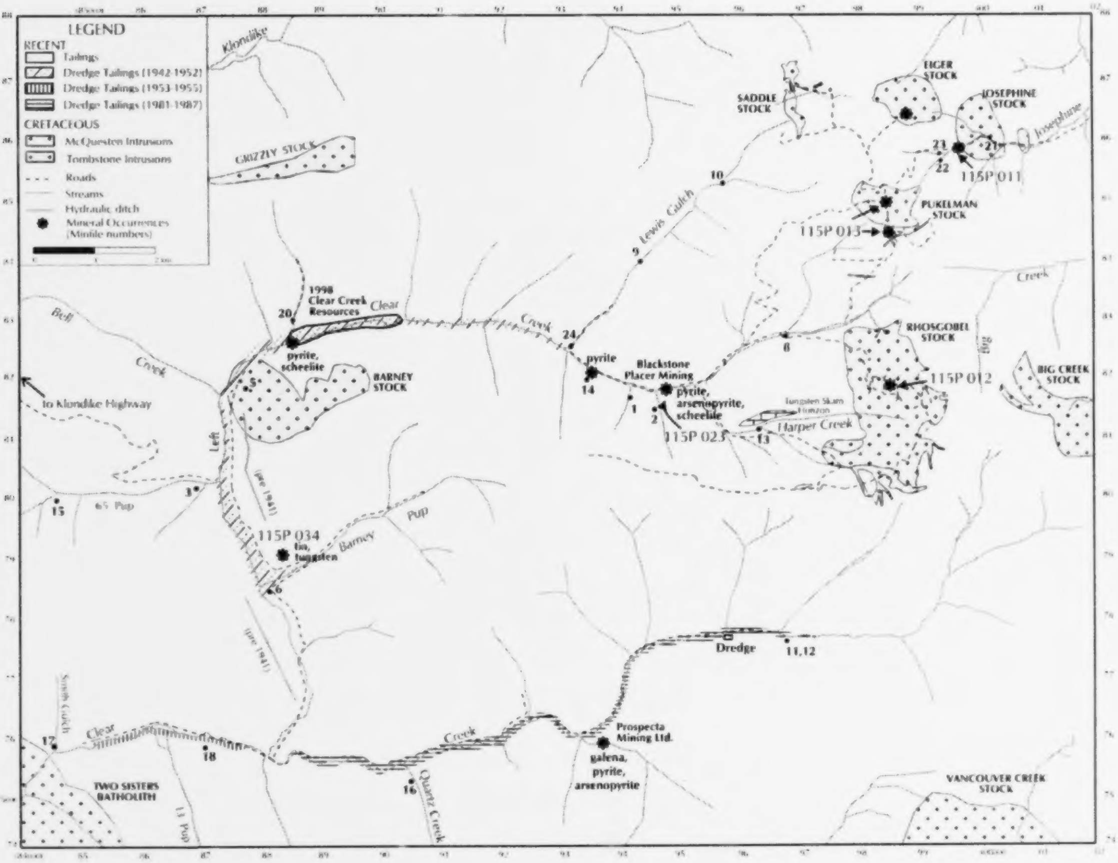
LEGEND
RECENT
Tailings
Dredge Tailings (1942-1952)
Dredge Tailings (1953-1955)
Dredge Tailings (1981-1987)
CRETACEOUS
McQuesten Intrusions
Tombstone Intrusions
Roads
Streams
Hydraulic ditch
Mineral Occurrences (Minfile numbers)
Klondike
GRIZZLY STOCK
SADDLE STOCK
TIGER STOCK
JOSEPHINE STOCK
Josephine
115P 011
PUKELMAN STOCK
115P 013
Lewis Gulch
Creek
RHOSGOBEL STOCK
Big
115P 012
BIG CREEK STOCK
1998 Clear Creek Resources
Clear
Creek
pyrite, scheelite
BARNEY STOCK
pyrite
Blackstone Placer Mining
pyrite, arsenopyrite, scheelite
115P 023
Tungsten Skarn Horizon
Harper Creek
Bell
Creek
to Klondike Highway
Left
65 Pup
115P 034
tin, tungsten
Barney
Pup
Dredge
11,12
Smith Gulch
Clear
Creek
Prospecta Mining Ltd.
galena, pyrite, arsenopyrite
Quartz Creek
TWO SISTERS BATHOLITH
13 Pup
VANCOUVER CREEK STOCK

Figure 2. *Location map showing regions mined with the bucket-line dredge, as well as known and suspected heavy mineral occurrences. Suspected occurrences are based on local abundances of heavy minerals found associated with placer gold in sluice boxes. Note galena is reported in quartz veins near the Vancouver Creek stock. Geology modified from Murphy et al. (1996) and various assessment reports. See Yukon Minfile or Murphy (1997) for detailed descriptions and mineral occurrences.*

along Clear Creek including the lower reaches of the main drainage (near Barlow Creek), as well as the left and right forks.

The earliest documentation of mine workings was by Bostock, who, during a field visit in 1947, described a large overshot wooden wheel and a three inch (7.6 cm) wooden hydraulic monitor about 4 ft (1.22 m) long, fitted onto another piece of wooden pipe by a wooden ball and socket joint (Bostock, 1990). This apparatus was likely used in the 1910s or 1920s. Information on the history of hydraulicking on Clear Creek is sparse, with only mention of ditches dug opposite Barney Pup for hydraulicking purposes (Bostock, 1990).

In 1939, the first steel sluice boxes to be used in the Yukon were set up on the left fork of Clear Creek. These steel sluice boxes, 40 in (1.02 m) wide and 60 ft (18.3 m) long, were set into bedrock. The gravel was moved to the boxes by hydraulicking and a tractor with a dozer plough. The $1^1/_2$ cubic yard (1.15 m^3) diesel drag-line scraper was to be stationed at the lower end of the boxes to stack the tailings with an expected capacity of 1500 cubic yards (1146 m^3) per day (Bostock, 1941).

DREDGING

Historical dredging operations are the best documented and perhaps the most interesting mining activity on Clear Creek. A dredge processed the largest volume of gravel of any operations within the drainage. A bucket-line dredge operated on Clear Creek from 1942 to 1952 (left fork), 1953 to 1955 (confluence of left and right forks), and 1981 to 1987 (right fork), processing more gravel than all other mining methods.

The first prospecting for dredging was completed in 1939 on the left fork of Clear Creek by sinking steel caissons to bedrock and keeping the hole dry with a gasoline-driven Rex pump. All gravel from the hole was sluiced by discharge water from the pump (Bostock, 1941). Clear Creek Placers Ltd. (formerly Canadian Placers Ltd.) originally operated on the left fork of Clear Creek using drag-line equipment. In 1942, they discontinued their drag-line operations and constructed a pontoon-type steel-constructed dredge that operated on the left fork from 1942 to 1952, consecutively (Debicki, 1983a). Each season, bulldozers stripped approximately one mile (1.6 km) ahead of the dredge to thaw the ground for the following season, although the seasonal progress of the dredge was less than one mile. From 1942 to 1952, the dredge worked $4^1/_2$ miles (~7.2 km) of Left Clear Creek starting below Barney Pup (Bostock, 1990). The dredge worked its way upstream to the confluence of Lewis Gulch where it discontinued operations (Fig. 2) after concluding that all economic placers had been mined from this fork (Debicki, 1983a).

The dredge was moved at the end of the 1952 season and continued operations from 1953 to 1955, mining $1^1/_2$ miles (~2.4 km) of Clear Creek downstream from its confluence with Left Clear Creek (Fig. 2). Dredge operations were terminated in 1956 due to rising costs and fixed gold prices (Debicki, 1983a). The dredge was eventually dry-docked at the confluence. During its operation in the 1940s and 1950s the dredge processed an average of 230,000 cubic yards (175,720 m^3) of gravel annually at a grade of 41¢/cubic yard (Table 1).

In 1979, Queenstake Resources Ltd. undertook an aggressive placer exploration program and became interested in the placer potential of Clear Creek, performing a backhoe sampling program on the first 7 miles (11.2 km) of Right Clear Creek, and deemed it suitable for a dredging operation. Exploration work and bulk sampling indicated an average grade in the order of $8.00 to $10.00 per cubic yard with gold at $500 an ounce. This sampling program estimated reserves be in excess of 3 million cubic yards (2,292,000 m^3) of gravel, averaging 12 ft (3.66 m) in depth with an average mining width of 200 ft (61 m) (Queenstake Resources Ltd., 1980). In 1980, Queenstake Resources Ltd. acquired the old dredge on Clear Creek and following 16 years in "drydock," the dredge was christened "John W. Hoggan - Queenstake #1." Mr. Hoggan was the dredge superintendent during the mining of the left fork of Clear Creek from 1952 to 1956 and his brother, Greg Hoggan, was a member of the small team that carried out the renovation of the dredge (Queenstake Resources Ltd., 1981).

After over a million dollars worth of renovations and ground preparation, the dredge was back into operation on the right fork of Clear Creek in 1981. Renovations included upgrading the power plant from its original Vivian diesel generator 250 h.p. to a Caterpillar #3406 PCTA diesel-powered generator 265 Kw 275 h.p. Pumps used on the dredge included a high pressure pump for trommel spray pipe mounted in hull (3500 g.p.m. with a 50 foot (15.2 m) head) and a low pressure pump that delivered water to the head of the distributor sluices (1600 g.p.m. with 25 foot (7.6 m) head; Queenstake Resources Ltd., 1979).

For mining, the dredge was anchored to buried deadmen by starboard bow and stern cable lines, and port bow and port stern cable lines. The dredge pivoted on the spud and the digging bucket line moved in an arc of approximately 100 ft (30.48 m) by the bow lines. The dredge was capable of mining approximately 18 ft (5.5 m) ahead before lifting the spud and moving across the pond to start the next face. The maximum digging depth of the dredge was 20 ft (6 m) below water level, including 2 to 5 ft (0.6 to 1.5 m) of the underlying decomposed and fractured bedrock where gold was concentrated (Queenstake Resources Ltd., 1981). In one day the dredge could move a 200 foot (60.6 m) wide by 12 foot (3.6 m) deep mining face ahead by 20 to 40 ft (6 to 12 m). Ground was stripped in advance of the dredge by bulldozers.

The dredge, comprising seventy $3^1/_2$ cubic ft (1.15 m^3) buckets, could mine 85 to 150 cubic yards (65 to 114.5 m^3) per hour.

Table 1. *Annual recorded production for the Clear Creek drainage. Note: Fine ounces of gold represent gold that has been refined (removal of impurities).*

Production by Clear Creek Placers Ltd. (formerly Canadian Placers Ltd.) dredging operations

Year	Fine ounces gold	Production (cubic yards)	Other reported values (Dollar values below represent value of gold at that time)	Reference
1941	~2,289*	119,600	$77,470.60	Debicki, 1983a
1942	949.2	57,400	$27,861.68 (48.05¢/cubic yard)	Debicki, 1983a
1943	3 ,564.75	244,860	$137,242.95 ($38.5¢/oz)	Debicki, 1983a
1944	~5,492.6*		$190,000	Debicki, 1983a
1945			No information available	
1946	2,706.56	303,040		Debicki, 1983a
1947	2 491	318,000		Debicki, 1983a
1948	2,489.05	317,000	27.5¢/cubic yard (gold at $35/oz)	Debicki, 1983a
1949	3,301.96	239,400	812 fine oz silver	Debicki, 1983a
1950	4,715.84	419,700	1 205 fine oz silver 0.011 fine oz/cubic yard	Debicki, 1983a
1951	2,293.48		$85,516.89	Debicki, 1983a
1952	749.30	120,000	$25,517	Debicki, 1983a
1953	2,692.68	248,800	$93,466 (37.5¢/cubic yard) 0.012 crude oz/cubic yard	Debicki, 1983a
1954	2,368.94	202,000	$83,200 (40.5¢/cubic yard) 0.014 crude oz/cubic yard	Debicki, 1983a
1955	1,417.40	143,000	$49,120 (34.35¢/cubic yard) 0.012 crude oz/cubic yard	Debicki, 1983a
Total	**37,522**	**2,589,800**		

Production by several various operators on Clear Creek

Year	Crude ounce gold	Other	Reference
1956	289.49*	Fine oz	Debicki, 1983a
1957	376.84*	Fine oz	Debicki, 1983a
1958	217.35*	Fine oz	Debicki, 1983a
1961	300		Skinner, 1962; Green & Godwin, 1964
1962	689		Green & Godwin, 1963; 1964
1963	670	658 oz from 40,000 cubic yards 12 oz from 27,000 cubic yards	Green & Godwin, 1964
1964	950	70,000 cubic yards mined. Fine gold and fine-grained specularite (hematite) and magnetite in heavies	Green, 1965
1973	150		Sinclair & Gilbert, 1975
1978	385		Gilbert, 1986
1979	620		Gilbert, 1986
1980	938		Gilbert, 1986
1981	2,400		Gilbert, 1986
1982	2,689		Gilbert, 1986
1983	6,972		Gilbert, 1986
1984	2,991		Gilbert, 1986
1985	3,680		Placer Mining Section, 1996
1986	3,646		Placer Mining Section, 1996
1987	4,834		Placer Mining Section, 1996
1988	4,290		Placer Mining Section, 1996
1989	6,725		Placer Mining Section, 1996
1990	9,372		Placer Mining Section, 1996
1991	6,930		Placer Mining Section, 1996
1992	3,227		Placer Mining Section, 1996
1993	2,536		Placer Mining Section, 1996
1994	3,005		Placer Mining Section, 1996
1995	3,522		Mining Inspection Division, 1998
1996	2,292		Mining Inspection Division, 1998
1997	1,607		Mining Inspection Division, 1998
Total reported gold recovered from 1956-1997: 75,420 crude oz + 884 fine oz			

*oz calculated based on reported dollar value

The dredge was designed to process up to 350,000 cubic yards (267 400 m^3) per year depending on the length of the operating season and the depth of the gravel. For 1981, the dredge was expected to mine between 250,000 and 300,000 cubic yards (191,000 to 229,299 m^3) with a net operating profit of approximately $1.5 million (Queenstake Resources Ltd., 1980). Despite the capacity of the dredge, it only mined an average 200,000 cubic yards per year during the 1980s (Table 2).

The dredge operated seasonally full-time from 1981 to 1987. Reserves calculated at the property were based on a sampling program with 162 backhoe pits and a drilling program of 25 rotary drill holes carried out between 1979 and 1984. Remaining reserves, calculated in 1985, totalled 900,000 cubic yards of gravel at 0.011 ounces of gold per cubic yard (Gutrath, 1986). In 1987 the dredge terminated mining activities on Clear Creek due to low gold prices (INAC, 1988). Annual production reported for the dredge averaged 200,000 cubic yards (152,800 m^3) per year at a grade of $3.93/cubic yard, indicating that reserves remain. The dredge is presently situated where it discontinued operations on the right fork of Clear Creek (Fig. 2). Mining has not been attempted upstream from this locality.

Queenstake Resources Ltd., also conducted a program of drilling, seismic, and backhoe pit sampling program on Big Creek (Fig. 1; Queenstake Resources Ltd., 1980; 1981). The results, reserves in the order of 7 million cubic yards (10.5 million tons) of gold bearing gravel, suggested that although it is not a viable dredge prospect, the property, depending on metal prices and further testing, could support a bulldozer/sluice operation.

MINING TODAY

Mining continues today on the main drainage of Clear Creek as well as the right and left forks in regions where the dredge was unable to mine, such as the smaller tributaries, neighbouring alluvial benches, and beyond the dredge limits. Streaks of pay dirt were left behind along the shallow sides of the creek, in deep pockets, and up the tributaries. In 1998, only three operations were active on the right and left forks due to low gold prices (~$290/oz).

PRODUCTION HISTORY

We documented the recovery of 75,420 crude ounces (2346 kg) and 38,366 fine ounces (1193 kg) of placer gold from the Clear Creek drainage from 1941 to 1997 (Table 1). Data are from several sources including Queenstake Resources annual reports, placer mining industry reports published by DIAND, and GSC papers. Production data were not available for the years 1945, 1959, 1960, 1965-1972, 1974-1977. A calculation of total gold recovery for Clear Creek, based on annual averages for the years in which data is not available, as well as a conversion of fine to crude gold (based on 800 fineness) suggests that actual recoveries were over 129,000 crude ounces (4012 kg). The years with the greatest production correspond with the years that the dredge operated (1941-1955 and 1981-1987) and also from 1989 to 1991, which corresponds to years of high gold values (Fig. 3). Between the years 1989 and 1991 there were up to eleven operations active on Clear Creek. Since then the number of active operations on Clear Creek has dropped to four or five with the decreased value of gold.

It should be noted that production figures reported for placer gold in the Yukon are accepted as minimum values. Available data are derived only from placer gold sold outside the Territory. As a result, much of it goes unreported.

Table 2. *Annual production figures for Queenstake Resources Ltd. (data for 1985 is unavailable).*

Year	Crude ounces	Fine oz	Fineness	Production (cubic yards)	Grade (fine oz/cubic yard)	Operating Costs	Reference	Location
1981	1685			2000/day			Queenstake, 1981	63°47' 137°15'
1982	2020	1619	801	184,450	0.0088	$789,605	Gutrath, 1986	
1983	5252	4232	806	215,600	0.0196	$696,619	Gutrath, 1986	63°47' 137°13'
1984	2023	1586	784	193,880	0.0082	$744,345	Gutrath, 1986	
1985								
1986	1136	909*						
1987	849*	679		191,415	0.004		INAC, 1988	
Total	**15,000****	**9025***	**Average = 800**	**Average = 196,300**	**Average = 0.0101**			

*Gold figures estimated based on an average fineness of 800.

**Total value estimated using an average value for 1985 based on other reported figures

GLACIAL HISTORY

The McQuesten River drainage basin, including the Clear Creek region, was affected by the pre-Reid (early Pleistocene), Reid (middle Pleistocene), and McConnell (late Pleistocene) glacial periods. The pre-Reid glacial period, the most extensive glaciation in the Yukon with multiple stages, was the only event that directly affected the valleys of Clear Creek (Fig. 2). Pre-Reid glacial deposits include till, resedimented till, and glaciofluvial sediments on the lower slopes of the valley sides. Pre-glacial fluvial gravels deposited by multi-channelled river systems are preserved under 2 m of pre-Reid diamicton characterized by a clayey silt matrix with subrounded to rounded clasts, thought to represent a melt-out till (Morison, 1984). A series of resedimented melt-out till units, up to 5.5 m thick, overlie the diamicton. These deposits are massive with subangular to subrounded clasts within a silty sand to fine sand matrix separated by 10 cm thick beds of fine sand to grey clay (Morison, 1984). The pre-Reid fluvial system, as noted at the mouth of Left Clear Creek, was multi-channelled and auriferous (Morison, 1984). Alpine glaciers also formed during the pre-Reid glacial period in the headwaters of Left Clear Creek, however, most of the sediment from this glaciation has been eroded from the valley sides (Fig. 2).

Clear Creek is beyond both the Reid and McConnell glacial limits of the Cordilleran ice sheet (Bostock, 1966; Hughes et al., 1969). Local alpine glaciers formed during the Reid or McConnell glacial periods (Morison, 1984) in the neighbouring Josephine and Big creeks (Fig. 2). The northwest portion of Vancouver Creek and the divide over to the right fork of Clear Creek demonstrates a large U-shaped valley, suggesting previous glacial activity up southern tributaries of Clear Creek. As a result of the McConnell glaciation, fluvial systems eroded and downcut through thick pre-existing glacial deposits resulting in the formation of creek and gulch placer deposits.

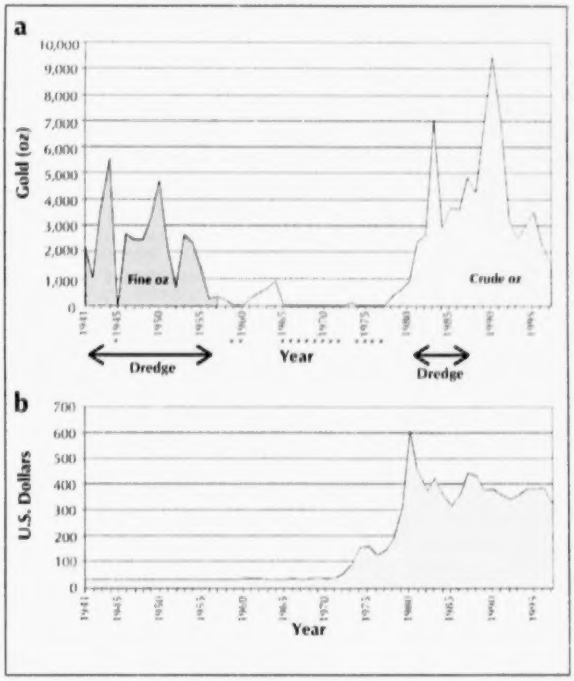

***Figure 3**. **a)** Reported gold production figures for Clear Creek from 1941 to 1997. Data are from several sources including Queenstake Resources annual reports and placer mining industry reports published by DIAND. Production data were not available for the years 1945, 1959, 1960, 1965-1972, 1974-1977 (marked by *). Total documented production is greater than 120,000 crude ounces. **b)** Annual average gold prices from 1941 to 1997.*

SURFICIAL GEOLOGY

Three gravel sections, exposed in mining cuts along the Clear Creek drainage, were measured and described in detail during the 1998 field season to determine the sedimentological character of the gravel deposits within the creeks (Fig. 4). These sections were measured at the mouth of Barney Pup (B), Harper's property (C), and a section approximately 1 km downstream from the confluence of the left and right forks of Clear Creek (A; Figs. 1 and 4). Each section displays a slightly different succession of gravels and associated sediments. No other sections were sufficiently exposed during this study due to depressed mining activity.

Surficial deposits noted in these sections include gravel, organic-rich silt and sand ("muck"); organic-poor sand, and diamicton. The most profitable placer deposits are in creek gravels underlying organic-rich silt and sand, most notably on Clear Creek. These gravels are unconsolidated, clast-supported, and contain well-rounded to subangular clasts ranging from pebble- to boulder-size. The matrix generally consists of a mixture of sand, silt, and granules. Clasts were derived from local rock types occurring within the drainage, including schist, quartzite, as well as rocks from nearby intrusions and dykes including granites, diorites, and lamprophyres. Gold is generally reported from the basal fluvial gravels directly overlying bedrock within the valley bottoms and adjacent benches of the Clear Creek drainage.

Lenses of muck, up to 7 m thick, are noted on Clear Creek near its confluence with Left Clear Creek. A few vertebrate fossils have been found within the muck deposits by local placer miners (Dean Klassen, pers. comm., 1998). The mucks on Clear Creek overlie auriferous fluvially washed gravel (Fig. 4). Other surficial deposits within the drainage include colluvial veneers and blankets, debris and sediment flow deposits, and alluvial fans, terraces, and plains (Morison, 1983a and b). Morison

(1983a) reported a radiocarbon date of 6230 ± 80 years from unknown material, perhaps wood, in valley bottom gravels from an unlocated section along the Clear Creek drainage, suggesting recent fluvial deposition.

Within the valley bottom, unmined gravels appear to be of fluvial origin, suggesting that they were not deposited directly by glaciers. The gravels may have been deposited by melt waters derived from local alpine glaciers, present during the pre-Reid glacial period, eroding and transporting gold from sources further upstream. Morison (1983a; 1984) interpreted these fluvial sediments as braided stream successions formed in an environment of high, fluctuating discharge levels.

BEDROCK GEOLOGY

The predominant bedrock in the upper reaches of Clear Creek include variably calcareous phyllite, schist and psammite of the Upper Proterozoic to Lower Cambrian Yusezyu Formation, Hyland Group (Murphy et al., 1996). The region is also underlain by several plutons belonging to two Cretaceous plutonic suites (Fig. 1). Members of the dominantly granite, ~64 Ma McQuesten plutonic suite outcrop in the southern portion of the study area and include the Two Sisters batholith and the Vancouver Creek stock. The ~91 Ma Tombstone plutonic suite include diorite to granite that outcrop at the headwaters of Left Clear Creek (Saddle, Eiger, Josephine, Pukelman, Rhosgobel, Josephine and Big Creek stocks), and the Grizzly and Barney stocks, in the western portion of the region.

MINERALIZATION

Numerous hardrock mineral occurrences have been discovered near the headwaters of Clear Creek, and undoubtedly influence the nature of the heavy mineral populations of creek gravel. The varied nature of mineralization within the drainage includes: intrusive-hosted, sheeted low-sulphide gold-scheelite quartz veins, arsenopyrite-rich quartz veins, auriferous disseminated and replacement-style sulphide mineralization, and tungsten skarns. Occurrences are well described in other reports (Emond and Lynch, 1990; Murphy et al., 1993; Murphy, 1997; Marsh et al., 1999) and occur within or adjacent to the six stocks at the headwaters of Clear Creek. Gold mineralization is

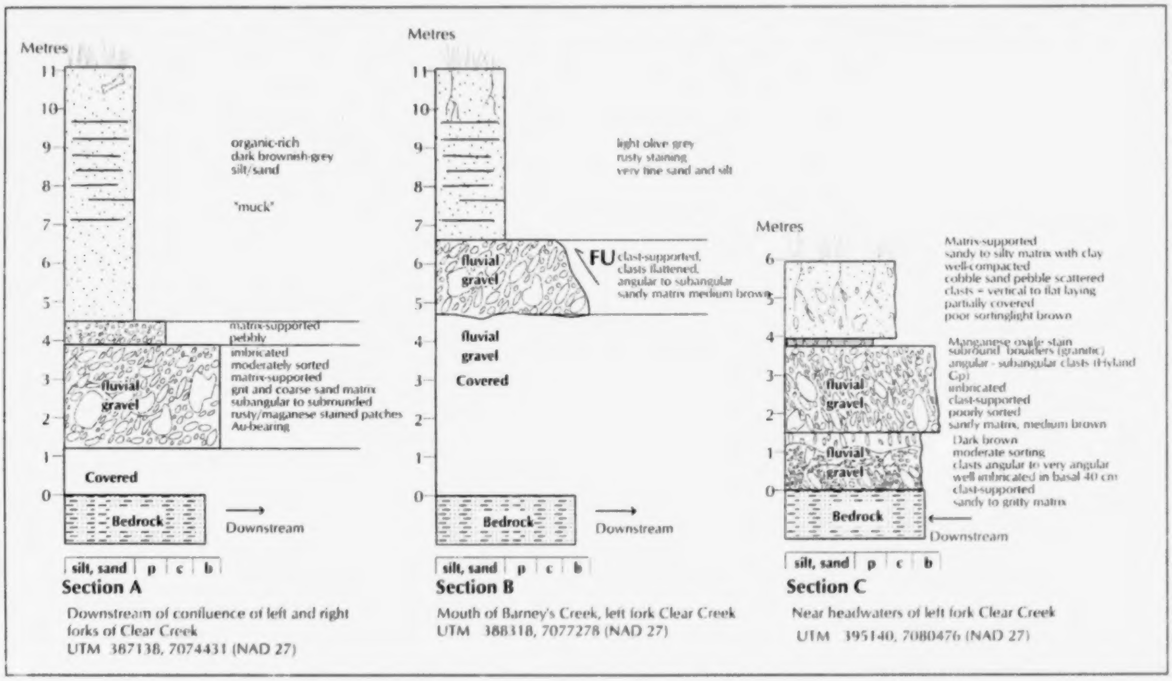
Metres
11
10
9
8
7
6
5
4
3
2
1
0
organic-rich
dark brownish-grey
silt/sand
"muck"
matrix-supported
pebbly
imbricated
moderately sorted
matrix-supported
grit and coarse sand matrix
subangular to subrounded
rusty/maganese stained patches
Au-bearing
fluvial
gravel
Covered
Bedrock
Downstream
silt, sand
p
c
b
Section A
Downstream of confluence of left and right forks of Clear Creek
UTM 387138, 7074431 (NAD 27)
Metres
11
10
9
8
7
6
5
4
3
2
1
0
light olive grey
rusty staining
very fine sand and silt
FU
clast-supported,
clasts flattened,
angular to subangular
sandy matrix medium brown
fluvial
gravel
fluvial
gravel
Covered
Bedrock
Downstream
silt, sand
p
c
b
Section B
Mouth of Barney's Creek, left fork Clear Creek
UTM 388318, 7077278 (NAD 27)
Metres
6
5
4
3
2
1
0
Matrix-supported
sandy to silty matrix with clay
well-compacted
cobble sand pebble scattered
clasts = vertical to flat laying
partially covered
poor sortinglight brown
Manganese oxide stain
subround boulders (granitic)
angular - subangular clasts (Hyland Gp)
imbricated
clast-supported
poorly sorted
sandy matrix, medium brown
Dark brown
moderate sorting
clasts angular to very angular
well imbricated in basal 40 cm
clast-supported
sandy to gritty matrix
fluvial
gravel
fluvial
gravel
Bedrock
Downstream
silt, sand
p
c
b
Section C
Near headwaters of left fork Clear Creek
UTM 395140, 7080476 (NAD 27)

Figure 4. Three sedimentological sections from the Clear Creek drainage illustrating the variation in sediment assemblages. The gravels characteristically show good imbrication consistent with the present day flow direction of the creek. Lithologies of clasts within the gravel reflect local bedrock, consisting of schistose, quartzite, and intrusive rocks. Gold is typically retrieved from gravels directly overlying bedrock. Underlying bedrock in each of these sections is Hyland Group schist and quartzite. Refer to Figure 1 for the location of these sections. FU = fining upward, p = pebble, c = cobble, and b = boulder.

largely characterized by an association with scheelite and arsenopyrite. Cassiterite, galena and tourmaline are also characteristic of mineral occurrences in the region.

Extreme enrichment of various heavy minerals, periodically revealed by placer miners, likely indicates proximity to mineral lodes. Hundreds of pounds of cassiterite were recovered per shift from gravel dredged for gold approximately 2 km upstream from Barney Pup during the 1940s (Bostock, 1990; Kreft, 1993). Downstream from Lewis Gulch the dredge hit a galena vein, although the position of the vein was never accurately located (Nels Harper, pers. comm., 1998). Dredging operations also intersected pockets of scheelite, although their precise locations were not documented. Recent placer mining, and our heavy mineral studies have revealed the presence and location of local concentrations of pyrite, arsenopyrite, scheelite, and galena, in addition to gold (Fig. 2). Massive pyrite bands up to 1 m thick were encountered by Blackstone Placer Mining through placer operations on Left Clear Creek in 1987 (Yukon Minfile). Placer mining operations on Right Clear Creek by Prospecta Mining Ltd. recovered large amounts of galena in their sluice box in 1998.

HEAVY MINERAL CONCENTRATE ANALYSIS

The evaluation of heavy mineral populations in placer gold environments has proven useful in determining mineralized hardrock sources (Gleeson, 1970; Boyle and Gleeson, 1971). We collected 29 panned samples from various localities along the left and right forks of Clear Creek for heavy mineral analysis to determine the relationship between bedrock at the headwaters and gravels deposited on the valley bottoms. Where possible, samples were collected from unmined gravel along the creek bed, on or near bedrock. In regions where extensive mining is active or has occurred in the past, samples were taken from washed or reworked gravel. The samples were panned in the field and dried for further separation. Four samples (98TLA25, 26 28, and 29) were concentrated in the sluice box where retrieved from placer operations and examined as is. The magnetic and other portions may have been removed from the sluicebox samples.

In the laboratory, the samples were further concentrated using the heavy liquid sodium polytungstate. Minerals and rock fragments with a specific gravity of greater than 2.889 sink to the bottom, while less dense fragments float to the surface and are removed. Although quick and toxic-free, the method does not produce a completely clean heavy mineral concentrate. Identification of the heavy minerals was performed using a binocular microscope, an ultraviolet lamp (short and long wave), and hand magnets.

The separated samples were then analyzed by the following procedure:

1. Estimation of the percentage of minerals that fluoresce under ultraviolet (scheelite, zircon).
2. Estimation of the percentage of magnetic minerals (magnetite, pyrrhotite, and artifacts).
3. Examination of the remaining minerals using a binocular microscope.

Grains studied from the panned heavy concentrates were generally less than 1.0 mm in diameter, making identification difficult. All results from this study are considered tentative, until confirmed by more sophisticated methods (e.g., X-ray diffraction, electron microprobe).

RESULTS

Previous heavy mineral studies have identified a wide range of minerals found in the Clear Creek drainage including scheelite, hematite, pyrite, magnetite, cassiterite, and arsenopyrite (Placer Mining Industry Reports, see Table 3). Heavy minerals identified in samples collected for this study include pyrite, arsenopyrite, and galena, as well as magnetite, ilmentite, scheelite, cassiterite, zircon, garnet, and hematite (Table 4). Unlike most placer occurrences in the Yukon, the heavy mineral concentrates are not dominated by magnetite, in fact most samples contained less than a few percentage of magnetite. However, many samples were dominated by ilmenite, commonly greater than 40%. Ilmenite-rich samples were typically obtained from tributaries draining intrusive rocks, in particular Left and Right Clear Creek and Lewis Gulch. The dominance of ilmenite over magnetite results from the reduced nature of the intrusive rocks (i.e., ilmenite series granites).

Hematite is common, but rarely occurs in significant quantities. Although small grains were probably derived from oxidized occurrences of metallic minerals, large hematite nuggets are exotic having been introduced by pre-Reid glacial drift (J. Bond, pers. comm., 1999). Cassiterite occurs as a trace amount in most samples and is locally crystalline. Significant quantities of cassiterite reported from early mining efforts, attest to a proximal source. Scheelite occurs as trace to a few percent in most samples but locally is greater than 5% from Josephine Creek and near the headwaters of Left Clear Creek. These localities are all downstream of known intrusive bodies (98TLA08, 14, 29) or skarn zones (98TLA13). Another isolated locality reported to have abundant scheelite (Clear Creek Resources, pers. comm., 1998) is near the bend on Left Clear Creek. This locality, currently being mined, is proximal to both the Grizzly and Barney stocks (Fig. 1).

Sulphide minerals were absent from most samples studied for this project. Where present, pyrite occurs as cubes (singular, twinned, and intergrown) as well as fine-grained granular aggregates. Some pyrite crystals are in quartz and grey schistose

Table 3. A summary of previously reported heavy mineral data of placer deposits of the Clear Creek drainage:

Locality	Fineness	Heavy minerals recovered (previously reported)								Reference
		galena	scheelite	hematite	pyrite	magnetite	cassiterite	arsenopyrite	Other minerals	
Clear Creek (downstream from confluence of right and left forks) 63°46' 137°16'	820 889								garnet	Placer Mining Section (1993) LeBarge and Morison (1990)
Squaw Creek 63°47' 137°28'	870									Debicki (1983b)
Upstream from Squaw Creek 63°45' 137°20'	840-850								black sand	Placer Mining Section (1991)
downstream from Squaw Creek 63°46' 137°34'	830						x		black sand	Placer Mining Section (1996)
downstream from Squaw Creek 63°47' 137°27'	840			x	x				black sand	Placer Mining Section (1991, 1993)
63°45' 137°15'	840			x					chalcopyrite	Placer Mining Section (1991)
Barlow Creek 63°48' 137°37'				x		x	x		sulphides	Placer Mining Section (1993)
Left Clear Creek			x			x	x	x		Kreft (1993)
1.6 km upstream from fork 63°46' 137°39'			x	x		x			barite	Placer Mining Section (1991)
7-9 km upstream from fork		x	x	x	x	x	x	x	ilmenite, garnet, barite, tourmaline, zircon	Aho (1949)
65 Pup 63°49' 137°19'	960					x				Placer Mining Section (1991, 1993)
Barney Pup 63°49' 137°15'	820-860					x	x		cinnabar	Debicki (1983b), Kreft (1993)
Bell Creek 63°51' 137°20'									black sand	Kreft (1993)
63°50' 137°07'	790-820									Placer Mining Section (1991)
Headwaters of left fork 63°51' 137°06'	730 820					x				LeBarge & Morison (1990); Placer Mining Section (1991)
Right Clear Creek			x	x		x	x			Kreft (1993)
1.6 km upstream from junction of the forks 63°47' 137°14'	820	x		x	x	x			(abundant pyrite)	Placer Mining Section (1996)
~ 3 km up from forks			x		x	x	x		ilmenite, garnet, zircon	Aho (1949)
Quartz Creek 63°46' 137°13'	790-820	x						x		Placer Mining Section (1996)
0.8 km upstream from Quartz Creek 63°46' 137°00'	840		x	x		x				Placer Mining Section (1991); Mining Inspection Division (1998)
Queenstake Resources on Right Clear Creek 63°47' 137°15'	828-860		x				x			Debicki (1983b)

Note: Galena on Right Clear Creek may be derived from galena-quartz veins near the Vancouver Creek stock (Murphy, 1997).

rock fragments. Arsenopyrite also occurs as singular and intergrown prismatic, striated crystals. Notable amounts of sulphide minerals occurred in the following samples (refer to Fig. 1 and Table 3 for sample locations):

- 98TLA05a – Fresh pyrite cubes (singular, twinned, and intergrown) are striated, or occur as compact granular aggregates; some in quartz.
- 98TLA26 – Pyrite (10-15%) occurs as fresh crystals, striated, cubic (singular, twinned) and granular aggregates (5%). Arsenopyrite (5%) occurs as elongate, striated, prismatic crystals that are brassy to silvery in colour; some twinned crystals.
- 98TLA28 – Fresh (bright metallic luster) pyrite cubes (singular, twinned, and intergrown masses), few crystals iridescent with green hue, also pseudomorphs of pyrite replaced by goethite and hematite and fine-grained granular aggregates. Some pyrite is attached to grey schist and quartz.

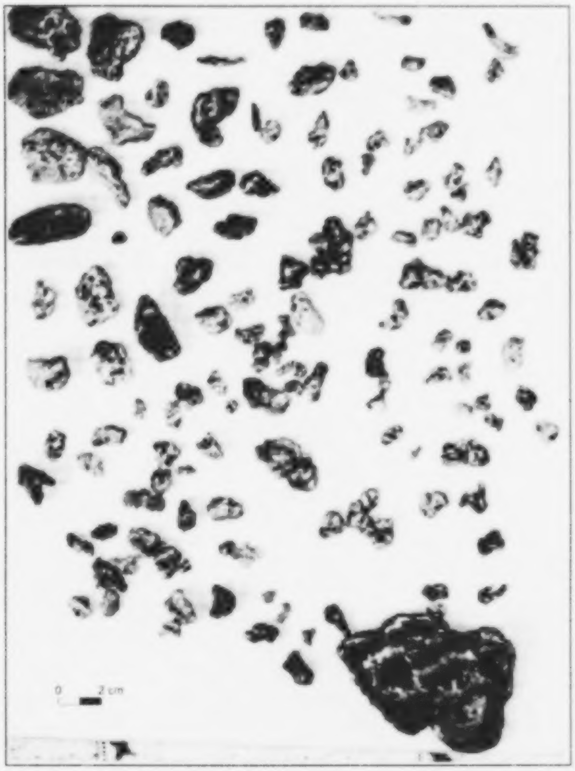

Figure 5. *Gold nuggets from the upper reaches of Left Clear Creek. The largest nugget reported from Clear Creek (7 oz) is shown in the bottom right hand corner.*

- 98TLA29 – Pyrite (15-20% of sample) is fresh, trace amounts of pyrite pseudomorphs replaced by goethite and hematite, or as pyritohedrons, cubes, and fine-grained aggregates of pyritohedrons (attached to quartz and/or grey schist). Galena (tr-1%) occurs as very fresh and silvery cubic crystals.

The high percentage of sulphide minerals in these samples, their association with quartz and schist, and degree of angularity suggests a probable derivation from a nearby source.

Zircon are present in trace amounts in most samples, as is sphene, but in higher quantities. Both are common minerals in felsic intrusive rocks, but are also present in the metasedimentary rocks. The highest quantities (>10%) of sphene are in drainages below intrusive rocks, notably creeks proximal to the Rhosgobel stock. Garnet is common and may be present as metamorphic minerals in the skarn (Sample 98TLA13), but has been observed (sparsely) in intrusive rocks. The Josephine Creek drainage also shows an appreciable amount of ilmenite, suggesting a close relationship may exist with the gravel and the intrusive bodies.

High percentages of magnetite may be indicative of drainages with retrograde skarn occurrences. Samples containing significant ilmentite, with sphene and zircon may be indicative of drainages with unmapped intrusive rocks. Significant hematite may indicate creeks draining pre-Reid tills.

GOLD DESCRIPTION (OBSERVATIONS AND ANALYTICAL)

On the main drainage of Clear Creek, placer gold is reported as fine and flat with few nuggets (Placer Mining Section, 1993, 1996; Mining Inspection Division, 1998). Gold recovered by the dredge on Right Clear Creek is generally tabular and worn, although some grains were rough and hackly (Debicki, 1983b). Less than 10% of dredged gold was coarser than No. 10 mesh (1.6 mm) while 90% was between No. 70 (0.19 mm) and No. 10 (1.6 mm) mesh (Gutrath, 1986). Gold retrieved from Left Clear Creek has been described as "fine and flat, though closer to the headwaters gold is coarser and rougher" (Kreft, 1993). Gold from 65 Pup consisted of coarse nuggets with 75% larger than No. 4 mesh (4.7 mm) mined from a 7 to 8 foot (2.1 to 2.4 m) thickness of channel gravel overlying decomposed schistose bedrock (Placer Mining Section, 1996). Overall, gold in the left and right forks of Clear Creek tends to be coarser than gold further downstream and west of the Two Sisters Batholith. The largest known nugget from the Clear Creek drainage, weighing 7 oz (218 g), was found near the headwaters of Left Clear Creek (N. Harper, pers. comm., 1998; Fig. 5).

Upon close inspection of the grains under a binocular microscope it is evident that there is a larger variation in the shape and roundness of the gold grains than previously reported

Table 4. *Summary of heavy mineral analysis of samples collected from the Clear Creek drainage. Samples 98TLA01 to 25 are panned concentrates, 26 to 29 are placer concentrates.*

Sample #	Locality/Operator	Easting UTM (NAD 27)	Northing UTM (NAD 27)	Yield	Coatings[1]	% dark mins[2]	rock frag	magnetite	scheelite	zircon	pyrite
98TLA01	Left Clear Creek, trib near Lewis deposit	394190	7080513	0.34 cm^3	very little		65-75%	5-15%	tr	1-2%	tr - pseudomorphs
98TLA02	Left Clear Creek, Harper's	394595	7080310	0.28 cm^3	very minor limonite	70%	50-60%	5-10%	tr-1%	tr-1%	1 fresh cube -striated; 1-2% pseudomorphs
98TLA03	65 Pup	397050	7079011	0.028 cm^3	limonite	10%	70-80%	tr	tr	2-5%	1% fresh cubes; pseudomorphs
98TLA04	Tributary east of Squaw Creek, off Clear Creek	381314	7075291	0.057 cm^3		40%	5-15%	10-20%	tr	1%	1% cubes; pseudomorphs
98TLA05a	Left Clear Creek, below Barney stock	387913	7080621	0.11 cm^3	very minor limonite	< 5%	1-5%	tr-1%	tr	1-5%	40-60% fresh cubes, striated, aggregates
98TLA05b	Below exposure of Barney stock	387913	7080621	0.057 cm^3	very minor limonite	70-80%	10-20%	tr	5-10%	1-2%	1 fresh cube, 2 pseudomorphs
98TLA06	Barney's Creek, Left Clear Creek	388178	7077337	0.11 cm^3		5-10%	60-70%	1-2%	tr	1-5%	1-3% pseudomorphs
98TLA07	Trench in scree below Rhosgobel stock	398452	7081589	0.028 cm^3	major limonite	90-95%	50-60%	tr-1%	tr	tr	
98TLA08	Left Clear Creek, junction of streams at upper end	396785	7081527	0.023 cm^3	heavy limonite	20-30%	5-10%	tr	20-40%	tr	tr fresh
98TLA09	Lewis Gulch	394365	7082786	0.05 cm^3	limonite	60-75%	5-10%	tr	1-2%	tr-1%	tr-1% cubes, pseudomorphs
98TLA10	Lewis Gulch, confluence near headwaters	395741	7084093	0.057 cm^3	limonite	60-80%	1-5%	tr-1%	1%	1%	tr pseudomorphs
98TLA11	Clear Creek, beyond dredge	396785	7076442	0.17 cm^3	minor limonite	80-90%	1%	1-5%	1-5%	1%	
98TLA12	Clear Creek, beyond dredge	396785	7076442	0.20 cm^3	limonite	90-95%	2-5%	1-5%	1-2%	1-2%	
98TLA13	Harper's Creek	396337	7079975	1.13 cm^3	very minor limonite	40-50%	5-10%	tr-1%	1-2%	tr	1% pseudomorphs, 1 fresh
98TLA14	Left Clear Creek, Harper's pay dirt	393461	7080800	0.17 cm^3	limonite	40-50%	10-20%	1-2%	10-15%	tr	tr - pseudomorphs
98TLA15	65 Pup	384642	7078813	0.11 cm^3	limonite	30-40%	75%	tr	<tr	tr-1%	1-5% pseudomorphs
98TLA16	Quartz Creek (across from Board's camp)	390502	7074107	0.39 cm^3		75-85%	70-80%	5-10%	<tr	1-5%	1% pseudomorphs
98TLA17	Smith Gulch, Klassen's (Clear Creek)	384593	7074710	0.11 cm^3	limonite	60-70%	5%	5%	tr	1-2%	1% pseudomorphs
98TLA18	Clear Creek, 13 Pup, Klassen's	387078	7074491	0.11 cm^3	minor limonite	60-70%	20%	2%	<1%	tr	1-2% pseudomorphs
98TLA19	Squaw Creek, Clear Creek, Scott's	378314	7075645	0.028 cm^3		75-90%	75-85%	1-3%	<tr	1%	1-2% pseudomorphs
98TLA20	Trib off Left Clear Creek,	388552	7081817	0.057 cm^3	limonite	20-30%	70-80%	1-5%	tr	tr	
98TLA21	Josephine Creek	400202	7084842	0.10 cm^3	major limonite	80-90%	50-60%	tr	1-5%	1%	tr pseudomorphs (single, twinned)
98TLA22	Josephine Creek	399388	7084446	0.028 cm^3	limonite	90-95%	40-50%	tr	5-10%	tr	tr, fresh; tr pseudomorphs
98TLA23	Josephine Creek	399360	7084584	0.11 cm^3	limonite	85-95%	10-20%	tr	1-5%	tr	tr, cubes
98TLA24	Lewis Gulch near confluence with Left Fork	393200	7081367	0.39 cm^3	limonite	85-95%	90%	tr	tr	tr	
98TLA25	Left Clear Creek, Blackstone Placer Mining	394854	7080663		magnetic Fe-stain			<1%	1-2%		
98TLA26	Right Clear Creek, Prospecta Mining Ltd., Board's	393706	7074724		iron-stained limonite, difficult to distinguish minerals	>50%	2-5% schist	tr	1%	tr	10-15% fresh, cubes, aggregates, crystalline, striated
98TLA28	Left Clear Creek, Clear Creek Resources	388407	7081400			10-15%	20-40%	tr	1-2%	tr	2-5% pseudomorphs, 25-40% fresh euhedral, cubes, pyritohedrons
98TLA29	Headwaters of Left Clear Creek, Blackstone Placer Mining, Harper's	394945	7080610			5-10%	5%	1%	65-80%	tr	5-7% cubic and pyritohedron

tr = trace amounts (<1%)

1 = coatings on the minerals causing difficulty in identification

2 = overall percentage of all dark minerals (i.e., magnetite, ilmenite, rock fragments)

Table 4. *...continued*

Sample #	cassiterite	garnet	hematite	ilmenite	sphene	hypersthene	epidote	anatase	pyroxene?	tourmaline?	gold	Other notes
98TLA01	tr	<tr		5-10%	1%	1%		<tr	1-2%	present		
98TLA02		< tr	1-5%	5-15%	tr	tr	tr					
98TLA03	tr	< tr		5-10%		1-2%	tr			tr - 1%		
98TLA04	tr	tr-1%	tr?	40-60%	1 grain	tr-1%		tr				
98TLA05a				1%	tr	tr	tr			2-5%		trace arsenopyrite
98TLA05b	tr			70-80%	1-5%	1%	tr	tr	1-2%	1-5%	4 grains, subcrystalline (0.1-0.2 mm)	
98TLA06	tr			1-5%		tr						
98TLA07				30-40%	tr	tr	tr		1-2%			
98TLA08	tr		1-2%	20-25%	15-20%	tr			tr	5%	3 grains; crystalline + quartz, subcrystalline (0.1, 0.2, 0.3 mm)	
98TLA09	< tr			65-75%		1%				tr		mins
98TLA10				60-80%	1-2%	tr					6 grains, sub-crystalline- crystalline	
98TLA11	tr	tr		85-90%	1 grain	tr-1%		tr	tr			
98TLA12	tr	1-2%		75-90%	1 grain	tr-1%		< tr	1-2%		1 grain, nugget (0.42 mm), subround	
98TLA13	tr-2%	2-5%		20-25%	25-30%							20-25% pyroxene? minerals
98TLA14	tr			30-40%	1-5%	1%					14 grains, flat, nugget, quartz attached (0.1 - 1.0 mm)	
98TLA15	< tr			1-5%		1-2%		< tr				
98TLA16	tr-1%	< tr		5-10%	tr	1-5%		< tr				
98TLA17	tr	1-5%		75-85%		1-3%		tr				
98TLA18	tr -2%	< tr		50-60%	tr	1-5%			tr	1%	5 grains flattened, subcrystalline	
98TLA19	tr-1%			5-10%		1%		tr		tr		
98TLA20		< tr		1-2%		tr				2-5%		
98TLA21	tr		1-5%	15-20%	tr-1%	tr		< tr	tr	1-2%	1 grain, crystalline (0.1 mm)	
98TLA22			5-10%	40-50%	1-3%	tr			tr	1-2%	1 grain, rod-shaped, rounded (0.15 mm long)	
98TLA23	< tr	< tr		60-70%	tr	tr			2-5%			
98TLA24	tr					tr	tr	< tr	2-5%	5%		
98TLA25												
98TLA26	present	tr (pink)	present	15-20%							crystalline, nugget, quartz attached (range 0.1 - 2.3 mm)	5-7% galena, 5% arsenopyrite, 2-5% unknown orangy-pink translucent mins, 20-30% orange, dull, non-crystalline minerals
98TLA28		2-5%	2-5%	5-10%							2 large grains (1.8 mm) mostly quartz with gold wrapped around, 2 small grains (0.4 mm) with quartz, crystalline to subcrystalline	unidentified orangy-pink translucent minerals, translucent white minerals
98TLA29		2-5%	tr-1%	5-10%							average 0.8-1.4 mm (0.1-2.0 mm)	trace galena, possible arsenopyrite

(Aho, 1949; Placer Mining Section 1991, 1993, 1996). Gold grains noted within panned heavy mineral concentrates in this study range from 0.1 to 1.0 mm in diameter and are sub-crystalline to crystalline (Table 5). Gold nuggets retrieved from sluice boxes are commonly $^3/_4$ to $1^1/_2$ oz (23 to 47 g), according to the placer miners. Gold grains observed in samples collected from Clear Creek range in shape from flat flakes to spheroidal forms and from well-rounded to crystalline (or hackly; Fig. 6). The percentage of gold grains with attached quartz varies between samples, with no apparent trend in distribution. These grains are typically sub-crystalline to crystalline (Table 5).

Panned samples containing gold typically contain a high percentage of ilmenite. Sample TLA9808, near the headwaters of Left Clear Creek, contained three grains of sub-crystalline to crystalline gold as well as fresh pyrite cubes and notable amounts of sphene, suggesting probable derivation from mineralization in or adjacent to the Rhosgobel stock.

Variations in placer gold fineness (purity) between creeks may indicate that the gold was derived from different lode sources. Fineness in Clear Creek gold varies ranging from 730 to 960 (Table 3). On the right fork, fineness averages 800, with a range of 784 to 860. The purity appears to be lower in the upstream limits. Purity of gold on the left fork ranges between 730 and

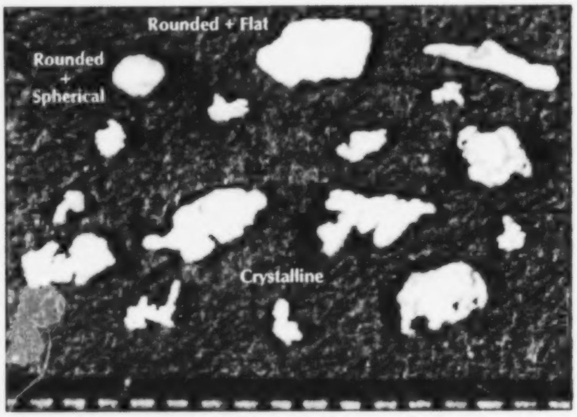

Figure 6. *Examples of various morphologies of placer gold from the right fork of Clear Creek. This photo illustrates the variability of the gold, ranging from rounded to crystalline and spherical to flat. Each tick on the scale represents 1 mm.*

Table 5. *Gold shape and roundness distribution for samples collected from active placer mining operations during the 1998 field season from Clear Creek. Sample number 98TLA26 is from Right Clear Creek, samples 98TLA28 and 29 are from Left Clear Creek. Gold grains were classified by presence of quartz, degree of roundness, and overall shape (flakes, branching, spheres, etc.). Staining on the gold grains is typically red to orange although occasionally black.*

98TLA26 (UTM 393706 7074724 (NAD27))

Gold Grains	**quartz**	**no quartz**	**flat**	**intermediate**	**spherical**	**branched**	**aggregate**	**stained**	**total**
round	0	32	8	12	10	2	0	9	19%
subround	5	61	16	11	8	12	19	21	39%
subcrystalline	17	37	6	5	6	21	16	25	32%
crystalline	9	9	1	0	7	9	1	7	11%
Total	**18%**	**82%**	**18%**	**16%**	**18%**	**26%**	**21%**	**36%**	

98TLA28 (UTM 388407 7081400 (NAD27))

	quartz	**no quartz**	**flat**	**intermediate**	**spherical**	**Total**
round						0%
subround		1			1	17%
subcrystalline	1				1	17%
crystalline	3			3		50%
Total	**80%**	**20%**	**0%**	**60%**	**40%**	

98TLA29 (UTM 394945 7080610 (NAD27))

Gold Grains	**quartz**	**no quartz**	**flat**	**intermediate**	**spherical**	**branched**	**stained**	**Total**
round	1	7	0	2	6	0	5	13%
subround	2	19	3	5	12	0	11	31%
subcrystalline	11	10	1	6	8	6	8	29%
crystalline	13	6	1	5	7	6	8	27%
Total	**39%**	**61%**	**7%**	**26%**	**49%**	**18%**	**34%**	

(Aho, 1949; Placer Mining Section 1991, 1993, 1996). Gold grains noted within panned heavy mineral concentrates in this study range from 0.1 to 1.0 mm in diameter and are sub-crystalline to crystalline (Table 5). Gold nuggets retrieved from sluice boxes are commonly $^3/_4$ to $1^1/_2$ oz (23 to 47 g), according to the placer miners. Gold grains observed in samples collected from Clear Creek range in shape from flat flakes to spheroidal forms and from well-rounded to crystalline (or hackly; Fig. 6). The percentage of gold grains with attached quartz varies between samples, with no apparent trend in distribution. These grains are typically sub-crystalline to crystalline (Table 5).

Panned samples containing gold typically contain a high percentage of ilmenite. Sample TLA9808, near the headwaters of Left Clear Creek, contained three grains of sub-crystalline to crystalline gold as well as fresh pyrite cubes and notable amounts of sphene, suggesting probable derivation from mineralization in or adjacent to the Rhosgobel stock.

Variations in placer gold fineness (purity) between creeks may indicate that the gold was derived from different lode sources. Fineness in Clear Creek gold varies ranging from 730 to 960 (Table 3). On the right fork, fineness averages 800, with a range of 784 to 860. The purity appears to be lower in the upstream limits. Purity of gold on the left fork ranges between 730 and

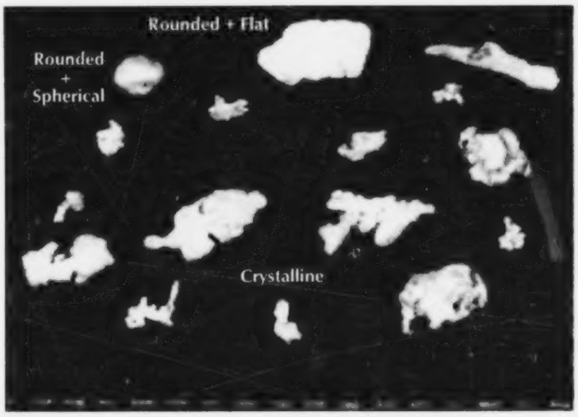

Figure 6. *Examples of various morphologies of placer gold from the right fork of Clear Creek. This photo illustrates the variability of the gold, ranging from rounded to crystalline and spherical to flat. Each tick on the scale represents 1 mm.*

Table 5. *Gold shape and roundness distribution for samples collected from active placer mining operations during the 1998 field season from Clear Creek. Sample number 98TLA26 is from Right Clear Creek, samples 98TLA28 and 29 are from Left Clear Creek. Gold grains were classified by presence of quartz, degree of roundness, and overall shape (flakes, branching, spheres, etc.). Staining on the gold grains is typically red to orange although occasionally black.*

98TLA26 (UTM 393706 7074724 (NAD27))

Gold Grains	**quartz**	**no quartz**	**flat**	**intermediate**	**spherical**	**branched**	**aggregate**	**stained**	**total**
round	0	32	8	12	10	2	0	9	19%
subround	5	61	16	11	8	12	19	21	39%
subcrystalline	17	37	6	5	6	21	16	25	32%
crystalline	9	9	1	0	7	9	1	7	11%
Total	**18%**	**82%**	**18%**	**16%**	**18%**	**26%**	**21%**	**36%**	

98TLA28 (UTM 388407 7081400 (NAD27))

	quartz	**no quartz**	**flat**	**intermediate**	**spherical**	**Total**
round						0%
subround		1			1	17%
subcrystalline	1				1	17%
crystalline	3			3		50%
Total	**80%**	**20%**	**0%**	**60%**	**40%**	

98TLA29 (UTM 394945 7080610 (NAD27))

Gold Grains	**quartz**	**no quartz**	**flat**	**intermediate**	**spherical**	**branched**	**stained**	**Total**
round	1	7	0	2	6	0	5	13%
subround	2	19	3	5	12	0	11	31%
subcrystalline	11	10	1	6	8	6	8	29%
crystalline	13	6	1	5	7	6	8	27%
Total	**39%**	**61%**	**7%**	**26%**	**49%**	**18%**	**34%**	

840. Fineness of gold retrieved from dredging operations in the 1980s averaged 800 (Gutrath, 1986; Table 3). No trends are apparent with data available. Sixty-five Pup is anomalous within the Clear Creek drainage, having a reported gold fineness of 900 to 960, making it the purest gold in the Yukon (Kreft, 1993). This may reflect a lode source of gold different than that contributing most gold to the Clear Creek drainage. Alternatively, gold with high fineness may be a function of considerable *in situ* leaching of the non-gold elements (Knight and McTaggart, 1990).

Variations in the shape, degree of roundness, and fineness of the placer gold from the Clear Creek drainage suggests that there are multiple sources and transporting mechanisms for the gold. A majority of the gold appears to be well travelled with a high degree of roundness and a general lack of quartz. Knight et al. (1994) recognized that gold particle roundness and flatness increase rapidly within the first 5 km of transport from the source, with flatness being the most reliable distance estimator. Hammering is the main cause of shape change in fluvially transported gold particles forming flattened grains (Knight et al., 1994). Some of the gold, with its sub-crystalline to crystalline form and association with quartz appears to be derived from a proximal source.

Successive glacial activity within the Clear Creek drainage likely played an important role in the distribution of gold from its source. Alpine glaciers, present during the pre-Reid, Reid, and McConnell glacial periods, and subsequent melt waters during interglacial periods travelling down and into the valleys, were likely important transport media for gold movement. The presence of large amounts of galena on Quartz Creek and along the right fork of Clear Creek suggests that the pre-Reid ice sheet or related meltwater may have transported galena from quartz veins near the Vancouver Creek stock. Alternatively, a local concentration of galena occurs on the right fork.

ACKNOWLEDGEMENTS

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REFERENCES

Aho, Aaro, E., 1949. Mineralogy of some heavy sands of the McQuesten River Area, Yukon. Unpublished BSc. Thesis, University of British Columbia, 48 p.

Bond, J. and Duk-Rodkin, A. (in progress). Surficial geology, McQuesten, Yukon Territory, Geological Survey of Canada, Open File, 1:250 000 scale map.

Bostock, H.S., 1941. Mining industry of Yukon 1939, 1940. Geological Survey of Canada, Memoir 234, p. 12-14.

Bostock, H.S., 1964. Geology, McQuesten River, Yukon Territory. Geological Survey of Canada, Map 1143A.

Bostock, H.S., 1966. Notes on glaciation in central Yukon Territory. Geological Survey of Canada, Paper 65-36, 18 p.

Bostock, H.S., 1990. Pack horse tracks - recollections of a geologist's life in British Columbia and the Yukon, 1924-1954. Geological Survey of Canada, Open File 650.

Boyle, R.W., 1979. The geochemistry of gold and its deposits. Geological Survey of Canada, Bulletin 280, 584 p.

Boyle, R.W. and Gleeson, C.F., 1971. Gold in the heavy mineral concentrates of stream sediments, Keno Hill area, Yukon Territory. Geological Survey of Canada, Paper 71-51, 8 p.

Debicki, R.L., 1983a. Yukon Mineral Industry 1941-1959. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, 136 p.

Debicki, R.L., 1983b. Placer Mining Industry 1978-1982. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs, p. 110-114.

Emond, D.S., 1982. Heavy minerals in the gravels of Highet Creek, Mayo mining district, Yukon Territory. Unpublished BSc. Thesis, University of Ottawa, Ottawa, 77 p.

Emond, D.S., 1986. Tin and tungsten veins and skarns in the McQuesten River area, central Yukon. *In:* Yukon Geology – Volume 1, Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 113-118.

Emond, D.S., 1989. Yukon Exploration 1988. Exploration and Geological Services Division, Yukon. Indian and Northern Affairs Canada, p. 224-229.

Emond, D.S. and Lynch, T., 1990. Geology, mineralization, and geochemistry of tin and tungsten veins, breccias and skarns, McQuesten River region (115 P (north) and 105 M 13), Yukon, *In:* Yukon Geology; Exploration and Geological Services Division, Yukon, Indian and Northern Affairs, Canada, vol. 3, p. 133-159.

Gilbert, G.W., 1986. Yukon placer mining industry 1983-1984. Mineral Resources Directorate, Yukon, Indian and Northern Affairs Canada, p. 95-99.

Gleeson, C.F., 1970. Heavy mineral studies in the Klondike Area, Yukon Territory. Geological Survey of Canada, Bulletin 173, 63 p.

Green, L.H., 1965. The mineral industry of Yukon Territory and southwestern district of MacKenzie 1964. Geological Survey of Canada, Paper 65-19, p. 65-66.

Green, L.H. and Godwin, C.I., 1963. Mineral industry of Yukon Territory and southwestern district of MacKenzie, 1962. Geological Survey of Canada, Paper 63-38, p. 57.

Green, L.H. and Godwin, C.I., 1964. The mineral industry of Yukon Territory and southwestern district of MacKenzie, Northwest Territories, 1963. Geological Survey of Canada Paper 64-36, p. 68-69.

Gutrath, G.C., 1986. Review of Queenstake's placer mining operations, Yukon Territory. *In:* Yukon Placer Mining Industry Report 1983-1984, G.W. Gilbert (ed.), p. 27-31.

Hughes, O.L., Cambell, R.B., Muller, J.E. and Wheeler, J.O., 1969. Glacial limits and flow patterns, Yukon Territory, south of 65°N latitude. Geological Survey of Canada, Paper 68-34, 9 p.

INAC, 1988. Yukon Exploration 1987. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 19, 20.

Knight, J.B. and McTaggart, K.C.,1990. Lode and placer gold of the Coquihalla and Wells areas, British Columbia, (92H and 93H). British Columbia Department of Mines, Exploration in British Columbia 1989, p. 105-118.

Knight, J.B., Mortensen, J.K. and Morison, S.R., 1994. Shape and composition of lode and placer gold from the Klondike District, Yukon, Canada. Exploration and Geological Services Division, Indian and Northern Affairs Canada, Yukon. Bulletin 3, 142 p.

Kreft, B., 1993. Placer mining and exploration compilation (NTS 105M and 115P). Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada; Open File 1993-10 (G).

LeBarge, W.P. and Morison, S.R., 1990. Yukon placer mining operations 1985 to 1988. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 122-131.

Marsh, E.E., Hart, C.J.R., Goldfarb, R.J. and Allen, T.L., 1999 (this volume). Geology and geochemistry of the Clear Creek gold occurrences, Tombstone gold belt, central Yukon Territory. *In:* Yukon Exploration and Geology 1998, C.F. Roots and D.S. Emond (eds.), Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 185-196.

Mining Inspection Division, 1998. Yukon placer mining industry 1995, 1996, 1997. Mineral Resources Directorate, Yukon, Indian and Northern Affairs Canada, p. 131-138.

Morison, S.R., 1983a. A sedimentologic description of Clear Creek, fluviatile sediments 115 P, central Yukon. *In:* Yukon Exploration and Geology 1982, Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 50-54.

Morison, S.R., 1983b. Surficial geology of Clear Creek drainage basin, Yukon Territory (NTS sheets 115 P/ 11,12,13,14). Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, Open File 1983-2 (1:50 000 scale).

Morison, S.R., 1984. Placer deposits of Clear Creek Drainage Basin 115P, central Yukon. *In:* Yukon Exploration and Geology 1983, Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 88-93.

Murphy, D.C., Héon, D. and Hunt, J.A., 1993. Geological overview of Clear Creek map area, western Selwyn Basin. *In:* Yukon Exploration and Geology 1992; Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 61-69.

Murphy, D.C., Héon, D. and Hunt, J.A., 1996. Geological map of Clear Creek area western Selwyn Basin, Yukon Territory (115P/14). Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, Geoscience Map 1996-1, 1:50 000 scale.

Murphy, D.C., 1997. Geology of the McQuesten River Region, Northern McQuesten and Mayo map areas, Yukon Territory (115P/14, 15, 16: 105 M/13,14). Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, Bulletin 6, 122 p.

Skinner, R. 1962., Mineral industry of Yukon Territory and southwestern District of MacKenzie, 1961. Geological Survey of Canada, Paper 62-27, p. 16.

Placer Mining Section 1991. Yukon placer mining industry 1989 to 1990. Mineral Resources Directorate, Yukon, Indian and Northern Affairs Canada, p. 60-67.

Placer Mining Section 1993. Yukon placer mining industry 1991 to 1992, Mineral Resources Directorate, Yukon, Indian and Northern Affairs Canada, p. 107-110.

Placer Mining Section 1996. Yukon placer mining industry 1993 to 1994. Mineral Resources Directorate, Yukon, Indian Affairs and Northern Development, p. 108-114.

Queenstake Resources Ltd., 1979. Revised dredge application information report. Right Fork Clear Creek placer project, Dawson Mining District, NTS 115P-14, prepared on behalf of Queenstake Resources Ltd., for Indian and Northern Affairs Canada.

Queenstake Resources Ltd. 1980, 1981. Annual Reports

Yukon Minfile. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada. Also available from Hyperborean Productions, Whitehorse, Yukon.

APPENDIX. REVIEW OF REPORTED ACTIVITIES ALONG CLEAR CREEK

YEAR	ACTIVITY
1900	T. Spritzer and J. Gergich - began work on discovery claim (Kreft, 1993)
1931	T. Spritzer and J. Gergich - staked a new discovery claim near the forks causing a small rush in the area (Kreft, 1993)
1936	Fairbanks Exploration Co. - explored Clear Creek
1937	Fairbanks Exploration Co. - started prospecting at the mouth of Barlow Creek with a light drill, but the results were not satisfactory as the drill proved unsuitable for the type of ground (Bostock, 1938)
1938	Dumont Brothers and Mr. E.N. Patty (Manager for General A.D. McRae) - Clear Creek
1939	March - Canadian Placers, Ltd., started prospecting on the left fork of Clear Creek (Patty = manager, O'Neill = superintendent)
1940	A complete mining unit for this operation was landed by boat on the north fork of Stewart River (Bostock, 1941)
1942-1952	Dredge (Clear Creek Placers Ltd.) operated on left fork of Clear Creek
1953-1956	Dredge (Clear Creek Placers Ltd.) operated on right fork of Clear Creek
1956	G. Fant and I. Norbeck mined ground on left Clear Creek optioned from Clear Creek Placers Ltd. (recovered 289.49 fine oz gold; Debicki, 1983)
1957	G. Fant and I. Norbeck mined on the left fork on a few claims of their own and ground leased from Clear Creek Placers (recovered 376.84 fine oz gold; Debicki, 1983)
1958	Fant and Norbeck continued mining Left Clear Creek, retrieving 217.35 fine oz gold. They ceased mining in 1958 due to low grades, moving to Hunker Creek (Debicki, 1983)
1961-1962	G. Heitman and H. Netzel mined below the main fork on Clear Creek. The ground mined at this time was ground previously stripped in preparation for dredging.
1963	G. Heitman and H. Netzel, F. Caley and G. Caley (Left Fork)
1964	Heitman and C. Janus
1973	Six operations were active on Clear Creek: William Scott/Larry Logie /V. Norby (Clear Creek Gold Mines) mined on the left fork near Barney Pup and Terry Thompson *et al.* (downstream from Squaw), W. Malicky *et al.* (upper part of left fork), C. Ames (Squaw Creek)
1974	William Scott/L. Logie (Clear Creek Gold Mines) and A. Genier/T. Thompson (mined side pay adjacent to dredge tailings just upstream from Barney Pup)
1975	W. Genier and T. Thompson (upper part of left fork), Clear Creek Gold Mines (mouth of Barney Gulch)
1976	Clear Creek Gold Mines (W. Scott and L. Logie) (Barney Gulch); T. Thompson and W. Genier (2000 ft downstream of Lewis Gulch) and G. Regimbald (4 mi upstream from mouth of Barlow)
1977	Clear Creek Gold Mines (W. Scott and L. Logie)
1978	Five operations were active — Birch Industries, Crescent Mines Ltd., Clear Creek Gold Mines (Barney Pup, 65 Pup), Blackstone Placer Mining (left fork), T. Bazylinski (left fork),
1979	Five operations were active — Crescent Mines Ltd., R. Lazotte and W. Genier, Clear Creek Gold Mines (65 Pup), Blackstone Placer Mining (left fork), T. Bazylinski (left fork), Arch Creek Mining Ltd. and Canada Tungsten Mining Corp. (Josephine Creek)
1980	The price of gold more than doubled to $800/oz. Seven operations were active - Crescent Mines Ltd., Squaw Creek Mining (Squaw Ck), Sundance Gold Ltd., R. Lazotte and W. Genier, Clear Creek Gold Mines (65 Pup), Blackstone Placer Mining (left fork), T. Bazylinski (left fork), Arch Creek Mining Ltd. and Canada Tungsten Mining Corp. (Josephine Creek). The dredge was acquired by Queenstake Resources Ltd.
1981	Nine operations were active — Barlow Lake Gold Mines Ltd., Raleigh Energy Corporation, Dawson Mining Equipment Ltd. (Zinc Ck), Crescent Mines Ltd., Squaw Creek Mining (Squaw Ck), Sundance Gold Ltd, Blackstone Placer Mining (left fork), T. Bazylinski (left fork), Queenstake Resources (right fork), Arch Creek Mining Ltd. and Canada Tungsten Mining Corp. (Josephine Creek)
1982	Seven operations were active — Dawson Mining Equipment Ltd. (Zinc Ck), Litchfield mining (Barlow Ck.), Crescent Mines Ltd., Squaw Creek Mining (Squaw Ck), General Mining (left fork), Blackstone Placer Mining (left fork), Queenstake Resources (right fork), Arch Creek Mining Ltd. and Canada Tungsten Mining Corp. (Josephine Creek)
1983	Eight operations were active — D. Buerge (Zinc Creek), Barlow Creek Mines (Barlow Creek), Auriferous Placers (Squaw), 3641 Yukon Ltd. (left fork), J. Scott (65 Pup), Blackstone Placer Mining Ltd. (left fork), T. Bazylinski (left fork), Queenstake Resources (right fork)

continued...

APPENDIX (continued)

YEAR	ACTIVITY
1984	Nine operations were active – D. Buerge (Zinc Creek), Barlow Creek Mines (Barlow Creek), Auriferous Placers (Squaw), 4757 Yukon Ltd., 3641 Yukon Ltd. (left fork), J. Scott (65 Pup), Blackstone Placer Mining (left fork), T. Bazylinski (left fork), Queenstake Resources (right fork)
1986	Two operations were active – R.E. Moore (Barlow), Queenstake Resources (right fork)
1987	Five operations were active – 4757 Yukon Ltd., T. Bazylinski (left fork), Blackstone Placer Mining (left fork), Van Bibber Placer, Queenstake Resources (right fork)
1981-1987	The dredge, the only bucket-line dredge, operated full-time. In 1987 the dredge terminated its mining activities on Clear Creek due to low gold grades (INAC, 1988).
1988	Four operations were active – 4757 Yukon Ltd., T. Bazylinski (left fork), Blackstone Placer Mining (left fork), Van Bibber Placer
1989	Eleven operations were active – E. Chesney (left fork), 4757 Yukon Ltd., Prospecta Contracting Ltd. (right fork), West Coast Paving, Nechako Contracting, T. Bazylinski (left fork), Blackstone Placer Mining (left fork), Gordon's Placer, N. Duncan, J. Scott (65 Pup), Van Bibber Placer
1990	Ten operations were active – E. Chesney (left fork), 4757 Yukon Ltd., Prospecta Contracting Ltd. (right fork), West Coast Paving, Nechako Contracting, Blackstone Placer Mining (left fork), Sister Resources, Gordon's Placer, J. Scott (65 Pup), Van Bibber Placer
1991	Seven operations were active – R. Jarvis, R. Lizotte (Barlow), West Coast Paving, Blackstone Mining (left fork), Sisters Resources, 4757 Yukon Ltd., J. Scott (65 Pup)
1992	Seven operations were active – R. Jarvis, R. Lizotte (Barlow), West Coast Paving, Blackstone Mining (left fork), Sisters Resources, 4757 Yukon Ltd., J. Scott (65 Pup)
1993	Nine operations were active – W. Wasylenko, R. Lizotte (Barlow), West Coast Paving, 4757 Yukon Ltd., Blackstone Placer Mining (left fork), L. Austin (Quartz Ck.), Prospecta Mining (right fork), J. Scott (65 Pup), Stoney Mines (65 Pup)
1994	Nine operations were active – W. Wasylenko, R. Lizotte (Barlow, right fork), West Coast Paving, 4757 Yukon Ltd., Blackstone Placer Mining (left fork), L. Austin (Quartz Ck.), Prospecta Mining (right fork), J. Scott (65 Pup), Stoney Mines (65 Pup)
1995	Eight operations were active – W. Wasylenko, R. Lizotte (Barlow), D. Kosuta, J. Scott, 4757 Yukon Ltd., Blackstone Placer Mining (left fork), Prospecta Mining (right fork), L. Austin (Quartz Ck.)
1996	Nine operations were active – W. Wasylenko, R. Lizotte (Barlow), D. Kosuta, J. Scott (65 Pup), 4757 Yukon Ltd., Stoney Mines (65 Pup), Blackstone Placer Mining (left fork), Prospecta Mining (right fork), L. Austin (Quartz Ck.)
1997	Five operations were active – W. Wasylenko, J. Scott (65 Pup), 4757 Yukon Ltd., Blackstone Placer Mining (left fork), Prospecta Mining (right fork)
1998	Blackstone Placer Mining (left fork), Prospecta Mining (right fork), Clear Creek Resources (left fork)

Placer deposit grain size and water quality sampling program

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Nowosad, M. and LeBarge, W. 1999. Placer deposit grain size and water quality sampling program. *In:* Yukon Exploration and Geology 1998, C.F. Roots and D.S. Emond (eds.), Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 215-222.

ABSTRACT

A program of placer deposit sediment and water sampling was initiated by Indian and Northern Affairs Canada (DIAND) in the summer of 1998 to investigate possible relationships between the grain size distribution of pay gravels and effluent levels at Yukon placer mines. The sedimentology of placer deposits may be characterized in one way by examining the grain size distribution of pay (gold-bearing) gravels. In addition, the amount of clay and silt in gold-bearing gravels has a direct bearing on the treatment necessary for gold liberation during the placer mining process, and the resulting use of water for this process. The program consisted of sampling the pay or sluiced portion of an actively mined placer deposit (bank material), in conjunction with instrument monitoring and sampling the water upstream and at the discharge point of the mine.

Knowledge of the grain size distribution of pay gravels will allow interpretation of the fluvial depositional environment, which can be used as a tool for placer deposit exploration. Sampling and analysis of the water will result in the ability to relate the grain size distribution of the active mine site (bank material) to the suspended solids concentration of the water, and the subsequent impact mining of the deposits has on the water quality in the area. This data will be important for the complete review of the Yukon Placer Authorization in 2001.

RÉSUMÉ

La caractérisation des sédiments des gisements alluvionnaires peut s'effectuer en étudiant la granulométrie des graviers rémunérateurs (aurifères). La teneur en argile et en silt des graviers aurifères influe directement sur le traitement requis pour libérer l'or au cours de l'exploitation des placers et sur l'eau utilisée lors de ce traitement.

Un programme d'échantillonnage des sédiments contenus dans les gisements alluvionnaires et de l'eau a été mis sur pied en 1998 (et se poursuivra en 1999) afin d'étudier les liens pouvant exister entre la granulométrie des graviers rémunérateurs et les débits d'eau chargée en sédiments des mines placériennes.

Le programme comporte l'échantillonnage de la portion rémunératrice ou lavée du gisement alluvionnaire en exploitation (matériaux de la rive) effectué conjointement avec la surveillance au moyen d'instruments et l'échantillonnage de l'eau en amont et au point d'évacuation de la mine.

La connaissance de la granulométrie des graviers rémunérateurs permettra d'interpréter l'environnement fluviatile, ce qui sera un atout pour l'exploration d'autres gîtes alluvionnaires. L'échantillonnage et l'analyse de l'eau permettront de développer une capacité à établir un lien entre la granulométrie d'une mine en cours d'exploitation (matériaux de la rive) et la concentration de matières en suspension dans l'eau, et l'impact ultérieur qu'aura l'exploitation des gisements sur la qualité de l'eau de la région. Ces données seront importantes lors de l'examen complet des placers du Yukon qui se fera en 2001 dans le cadre de la délivrance de permis d'exploitation.

INTRODUCTION

The Yukon Placer Authorization (YPA; Mining Inspection Division, 1993) is the document that sets the standards for placer mine effluent discharge on Yukon streams. This authorization under the Fisheries Act gives powers of enforcement in the regulation of placer mining to Indian and Northern Affairs (DIAND). Standards in the YPA were based on limited information on placer deposit grain size distributions and baseline water quality data, and will be reviewed in 2001.

A database of grain size information for Yukon placer deposits is being developed to aid in this review. This will add to our sedimentological knowledge of these deposits, which may assist us in exploring for similar placer gold-bearing gravels. This information can also be used for mine planning purposes such as settling pond construction.

Simultaneously, a water quality database is being developed to establish baseline information on mined and unmined reaches of creeks throughout the Yukon. This will be used to test the effectiveness of the current YPA standards.

Since some of the YPA standards are not measurable in the field, instrumentation is also being designed and developed which should have this capability.

Two sites were chosen for instrument monitoring in 1998, Duncan Creek in the Mayo area and Nansen Creek in the Carmacks area (Fig. 1).

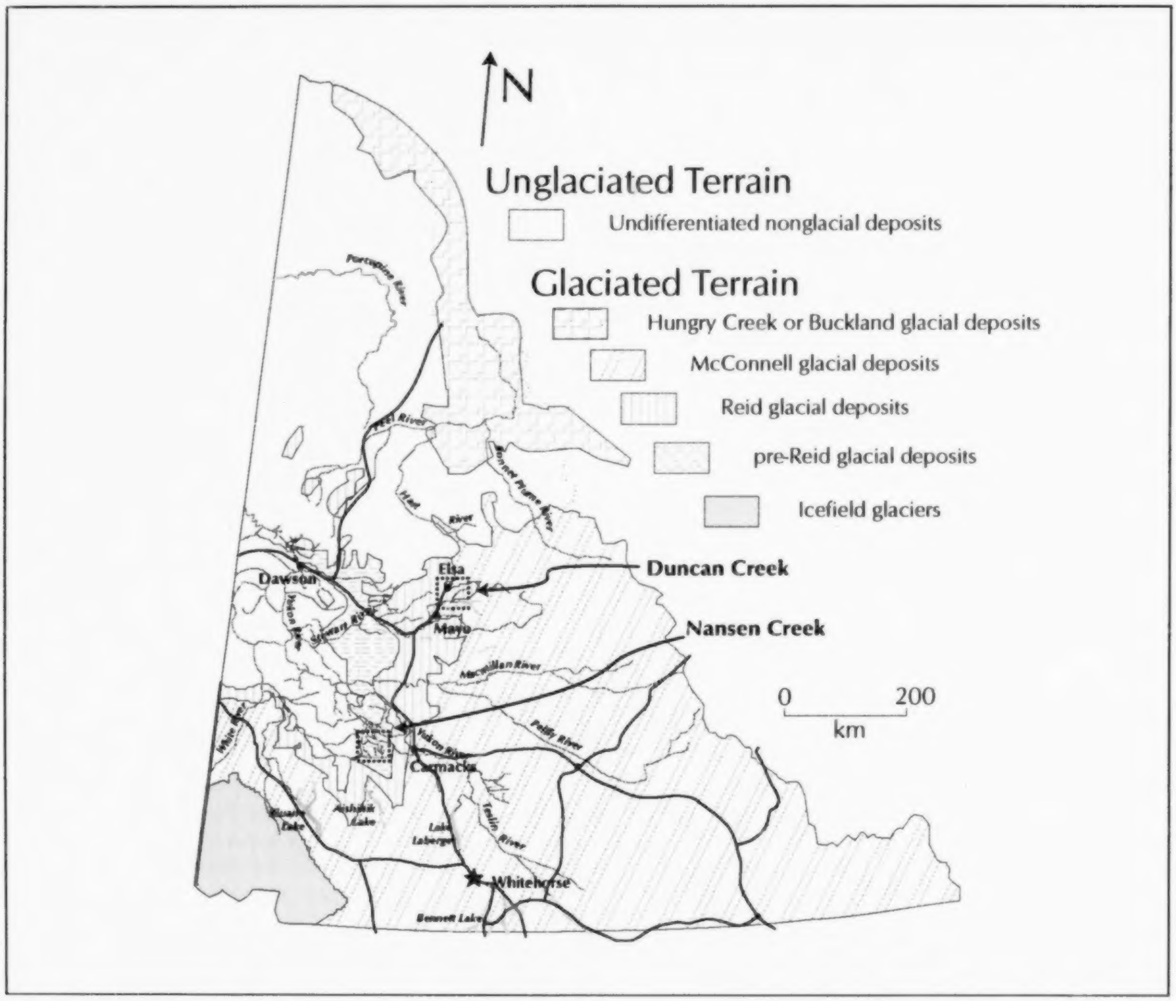
N
Unglaciated Terrain
Undifferentiated nonglacial deposits
Glaciated Terrain
Hungry Creek or Buckland glacial deposits
McConnell glacial deposits
Reid glacial deposits
pre-Reid glacial deposits
Icefield glaciers
Duncan Creek
Nansen Creek
0
200
km
Porcupine River
Peel River
Bonnet Plume River
Hart River
Dawson
Elsa
Mayo
Stewart River
Macmillan River
Pelly River
Yukon River
White River
Carmacks
Aishihik Lake
Kluane Lake
Lake Laberge
Teslin River
Whitehorse
Bennett Lake

Figure 1. Location of 1998 water monitoring sites and Cordilleran glacial ice limits in the Yukon.

PROGRAM OBJECTIVES

The objectives of this program are to learn more about placer deposit sedimentology for exploration purposes, and to characterize the impact of various placer deposit grain size distributions on water quality.

The sedimentology of placer deposits can be distinguished by analyzing their grain size distribution in addition to examining the interaction between these sediments and water, both in a laboratory setting and during the mining process. This will be accomplished by sampling the pay or sluiced portion of an actively mined placer deposit (bank material), in conjunction with monitoring and sampling the water upstream and at the discharge point of the mine.

METHODS

PLACER DEPOSIT SAMPLING PROGRAM

Pay gravels (feed materials) and barren overburden were systematically sampled (Fig. 2), site-specific sedimentologic and stratigraphic data was compiled, and additional information was gathered including amount of overburden stripped, volume of gravels sluiced and gold characteristics. In some areas pay gravels were resampled as they changed character throughout the mining season.

Using methods described in Folk (1974), grain size samples were dried, split and sieved to #10, #18, #35, #60, #120, #230 and minus #230 Tyler screens. After weighing the individual fractions, the #18 to #60 mesh fractions were saved for heavy mineral analysis and the minus #230 portion was sent to Okanagan University College for instrument analysis of the silt/clay ratio.

Figure 2. *Pay gravels and feed materials were sampled for grain-size analysis and gold content.*

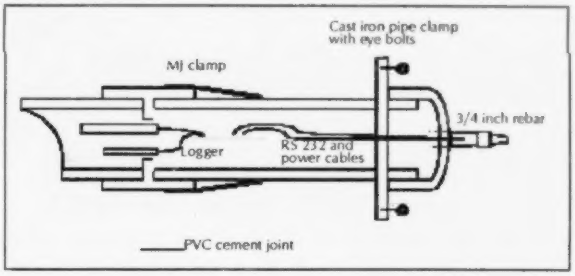

Figure 3. *"Waterpod" instrument developed by Okanagan University College, Kelowna, B.C.*

WATER QUALITY SAMPLING PROGRAM

The "WaterPod" (Fig. 3) is a water monitoring instrumentation package which was developed by Okanagan University College. It is designed to measure and log various physical and chemical parameters of flowing water in streams and rivers. This equipment allows the continuous collection of water quality data pertaining to individual streams in specific mining areas that, until recently, had been unobtainable (Okanagan University Technical Access Centre, 1998). The "WaterPod" has flexible monitoring capabilities and an on-board 512K memory for data collection and storage. The heart of the WaterPod is a specially designed data logger. The logger is capable of handling up to ten input channels at a time, each channel dedicated to monitoring a specific parameter. All of the components were mounted inside a 6-inch PVC weatherproof housing.

Parameter selective sensors measured the suspended solids concentration, temperature, total dissolved solids (TDS), conductivity, oxygen reduction potential (ORP) and pH in the flowing water. This equipment allowed the continuous collection of background data pertaining to individual streams and specific mining areas that up until now has been unobtainable.

DIAND Water Technologist Mark Nowosad deployed the instrumentation in the field, retrieved the collected data, and gathered individual corroborative water samples upstream and downstream of each of the active placer operations (Figs. 4 and 5). Feed material and process water were simultaneously sampled during placer mine operation.

Data was collected continuously at each site for a period of seven to ten days. The equipment was removed at the end of the season and returned to the university along with copies of the collected data. The university is currently correlating the data collected from the monitoring stations with the data collected from the placer deposit sampling program and the grain size analysis of the gravel samples. This will allow us to relate the surrounding sediment characteristics of the site to the suspended solids concentration of the water, and hence the impact mining of these deposits has on the water quality in the area.

DUNCAN CREEK AND MAYO RIVER

INTRODUCTION AND BACKGROUND

Duncan Creek is a located within the Mayo Mining District (Fig. 6), an area with a long history of placer and hard rock mining dating back to the turn of the century. Several studies have been conducted in this area in recent years, including the multidisciplinary Mayo Placer Research Project (LeBarge, 1996, LeBarge et al., in prep.), and several Master's theses (Giles, 1993, Weston, in prep.). The present study will complement previous research on the relationship between placer mining and suspended sediment in mining streams (Pentz et al., 1996). Each of Duncan Creek and Davidson Creek, both Mayo River tributaries, had one operating placer mine in 1998 (Fig. 7).

PHYSIOGRAPHY AND GLACIAL HISTORY

The Mayo area was affected by all three major episodes of Pleistocene glaciation in the central Yukon. These are (from oldest to youngest): pre-Reid (multiple episodes), Reid, and McConnell. While the Mayo area was completely inundated by the pre-Reid glaciation, it lies at the margins of both of the subsequent Reid and McConnell glaciation (Hughes, 1982, 1987).

Features of the pre-Reid glaciations are difficult to distinguish and mainly consist of erosional scars or glacial erratics on ridges above the Reid ice limit. Ice-contact features, such as moraines and meltwater channels associated with the Reid limit, are more evident but more subdued than the prominent moraines and glaciofluvial terraces associated with the McConnell ice limit.

LOCATION OF STATIONS

Stations were set up in six locations:

1) the confluence of Lightning Creek and Thunder Gulch,
2) immediately upstream of Duncan Creek GoldDusters mining operation,
3) Duncan Creek bridge, downstream of Duncan Creek GoldDusters,
4) Mayo River bridge above the confluence of Davidson Creek and the Mayo River,
5) Mayo River downstream of the confluence with Davidson Creek, and
6) Mayo River downstream of the confluence with Duncan Creek.

NANSEN CREEK

INTRODUCTION AND BACKGROUND

Nansen Creek is located within the Whitehorse Mining District, approximately 60 km west of the village of Carmacks (Fig. 8). Henry S. Back first discovered gold there in July, 1899 on a prospecting trip from Selkirk, when he found gold on Nansen Creek at the mouth of Discovery Creek. Frank H. Back and Tom Bee staked the Discovery claim on Nansen Creek on June 13, 1910 (Cairnes, 1915). Serious mining began to take place shortly thereafter, and nearly all creeks in the area were at one time staked end to end, although most of these claims were eventually allowed to lapse. There were four active mines in 1998, one on Nansen Creek (Fig. 9) and one on Slate Creek, a right limit tributary to Nansen Creek.

Figure 4. *Individual corroborative water samples were gathered upstream and downstream of each of the active placer operations.*

Figure 5. *"Waterpod" instruments were mounted on existing structures, such as bridges, whenever possible.*

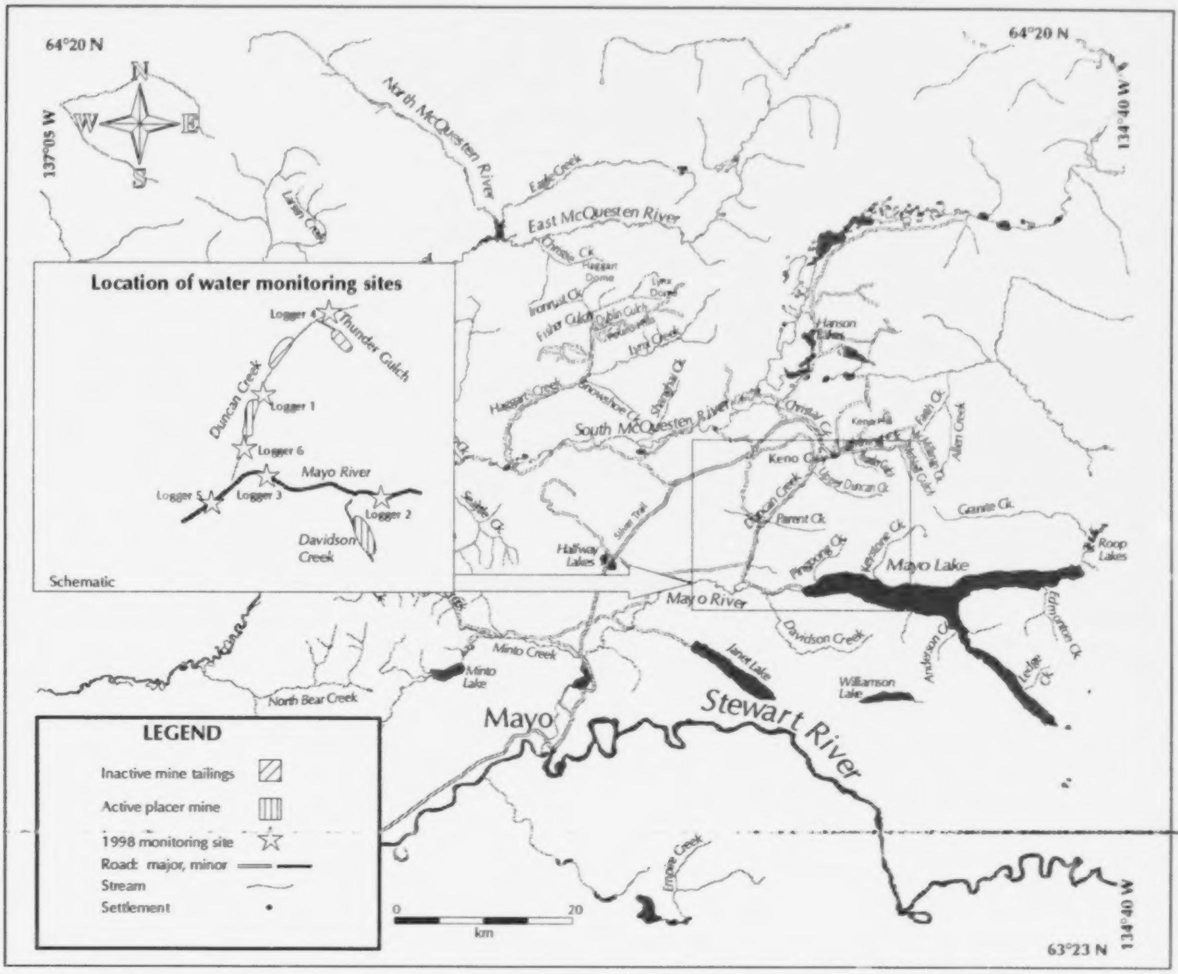
64°20 N
137°05 W
N
W
E
S
North McQuesten River
Eagle Creek
East McQuesten River
Haggart Dome
Lynx Dome
Ironrust Ck
Fisher Gulch
Dublin Gulch
Lynx Creek
Haggart Creek
Snowshoe Ck
South McQuesten River
Hanson Lakes
Keno Hill
Keno City
Faith Ck
Allen Creek
Upper Duncan Ck
Duncan Creek
Parent Ck
Granite Ck
Roop Lakes
Halfway Lakes
Silver Trail
Mayo Lake
Mayo River
Davidson Creek
Edmonton Ck
Ledge Ck
Anderson Ck
Williamson Lake
Janet Lake
Minto Creek
Minto Lake
North Bear Creek
Mayo
Stewart River
Location of water monitoring sites
Logger 4
Thunder Gulch
Duncan Creek
Logger 1
Logger 6
Mayo River
Logger 5
Logger 3
Logger 2
Davidson Creek
Schematic
LEGEND
Inactive mine tailings
Active placer mine
1998 monitoring site
Road: major, minor
Stream
Settlement
0
20
km
134°40 W
63°23 N

Figure 6. Location of 1998 water monitoring sites, Duncan Creek area.

Figure 7. Duncan Creek Golddusters mined on Duncan Creek in 1998.

PHYSIOGRAPHY AND GLACIAL HISTORY

Nansen Creek and its tributaries lie outside of the limits of the McConnell and Reid glaciations, however they are within the limits of at least two of the much earlier, pre-Reid glacial episodes (Bostock, 1966, Hughes, 1987). The economic placers in Nansen Creek occur upon a "boulder clay" horizon which may represent a till left by one of these early glaciations (Bostock, 1966). Placer gold also occurs within this till or diamicton, primarily at the diamicton/bedrock contact (LeBarge, 1993, 1995). Gravels are frozen, range in thickness from 1 to 8 m (averaging 5 to 6 m), with a moderate amount (0.5 to 3 m) of organic material. Many of the Mt. Nansen area gold placers lie above the treeline.

Other evidence of the pre-Reid glaciations includes scattered erratics on ridges and variously buried glaciofluvial terraces, meltwater channels and glacial till, some of which have a

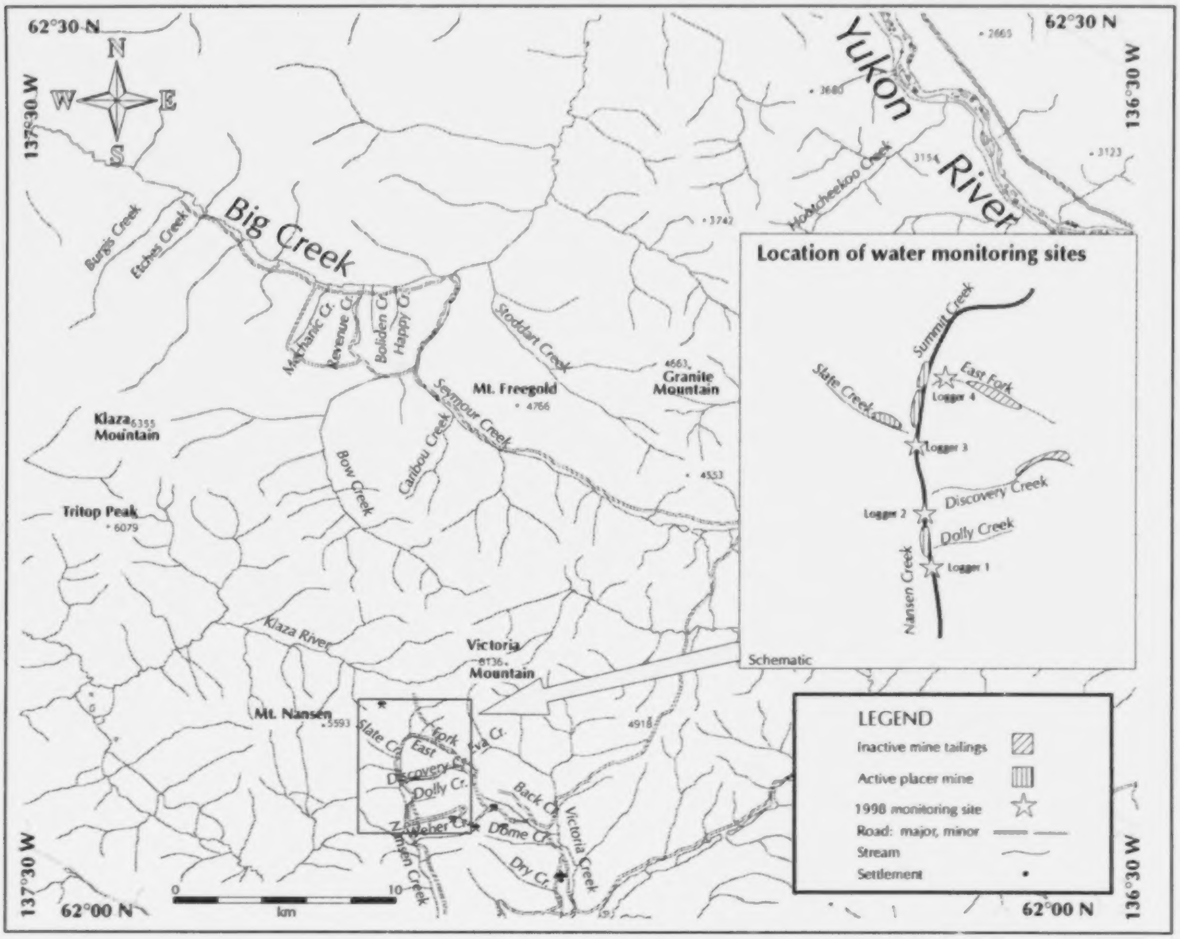
62°30 N
N
W
E
S
137°30 W
Yukon River
Hootchekoo Creek
2665
3680
3154
3123
3742
Burgis Creek
Etches Creek
Big Creek
Mechanic Cr.
Revenue Cr.
Boliden Cr.
Happy Cr.
Stoddart Creek
Mt. Freegold
4766
4663
Granite Mountain
Klaza 6355 Mountain
Seymour Creek
Caribou Creek
Bow Creek
4553
Tritop Peak
6079
Klaza River
Victoria 6136 Mountain
Mt. Nansen 5593
Slate Cr.
East Fork
Eva Cr.
Discovery Cr.
Dolly Cr.
Back Cr.
Weber Cr.
Dome Cr.
Nansen Creek
Dry Cr.
Victoria Creek
4918
0
10
km
62°00 N
136°30 W
Location of water monitoring sites
Summit Creek
East Fork
Logger 4
Slate Creek
Logger 3
Discovery Creek
Logger 2
Dolly Creek
Logger 1
Nansen Creek
Schematic
LEGEND
Inactive mine tailings ▨
Active placer mine ▥
1998 monitoring site ☆
Road: major, minor
Stream
Settlement •

Figure 8. *Location of 1998 water monitoring sites, Nansen Creek area.*

characteristic deep-red weathering surface known as the Wounded Moose paleosol (Foscolos et al., 1977). Large, sandy periglacial fans that formed during the Reid glacial period, just outside of the Reid ice limit, dominate the lower reaches and the major tributaries of Nansen and Victoria creeks. McConnell glacial deposits consist of wind-blown silt or loess which caps many of the gravel deposits.

LOCATION OF STATIONS

Monitoring stations were set up in four locations:

1) immediately downstream of Johnson Brothers mining operation on Nansen Creek,
2) approximately 300 m upstream of Johnson Brothers mining operation on Nansen Creek,
3) at the confluence of Slate Creek and Nansen Creek, and
4) at the confluence of Summit Creek and Nansen Creek.

DISCUSSION

The Mining Inspection Branch of DIAND has collected Yukon creek and river water samples for analysis for a number of years. The data collected from these samples, and the subsequent analysis of that data, indicates a non-conforming relationship exists between the turbidity level in some waters versus the suspended solids concentration. Some of the creeks (e.g., McBurney, Blackhills and Hunker) have a very high suspended solids concentration without a high turbidity value. Alternatively, several creeks (Henderson, Duncan and Little Gold) have high NTU (Nephelometric Turbidity Units) readings despite the fact that the suspended solids concentration is low (Mining Inspection Division, 1992-1997).

In these instances, apparent background colour and the texture class of the sediment in solution (sand vs. silt vs. clay) has a detrimental effect on turbidity readings[1]. Dissolved and

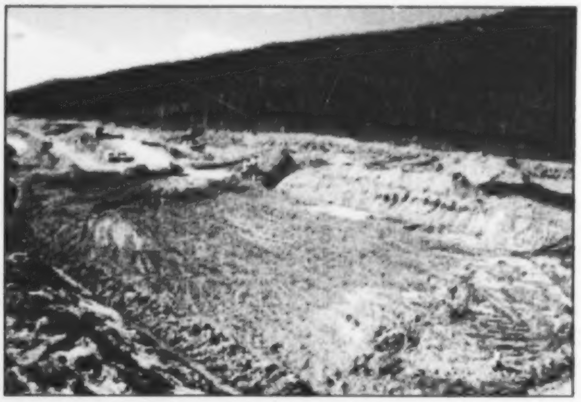

Figure 9. *Joex Mining (Johnson brothers) was the largest placer mine on Nansen Creek in 1998.*

suspended material, both organic and inorganic, can cause colouration of the water and reflect light (Hammer and Hammer, 1996). This can lead to high turbidity values and the mistaken assessment that the creek bears substantial suspended solids, when in fact their concentration is low. Turbidity is not a direct measure of suspended particles in water but instead, a measure of the scattering effect these particles have on light. The amount of light scattered by any particle depends on the particle's size, shape, composition and refractive index.

To further complicate the picture, only superior design allows sensors to compensate for the interference of background colour and varying particle matrix. Site specific field calibration is one method of improving the sensing of these fractions that have creek to creek variations. With the added effects of colouration and clay concentration, NTU values easily rise while the creek may have negligible suspended solids concentration. The alternate case of low NTU readings in conjunction with high suspended solids concentrations is more easily correlated as the NTU readings are not skewed by colour and particle interferences and therefore remain positively correlated with suspended solids.[2]

The Yukon Placer Authorization standards for suspended solids are measured in mg/L. Since DIAND would like to be able to predict these values using a suitable sensor, direct measurement of suspended solids using suspended solids sensors is recommended rather than trying to convert from turbidity readings. At this time, the alternate field measurement technique using turbidity as a standard has not been approved by the Minister.

TENTATIVE 1999 PROGRAM

The 1999 Program will expand the number of monitored sites to several new regions across the Yukon, in a number of different physiographic and geologic settings. There will be several more WaterPods available, and as many as 10 WaterPod stations per region may be deployed. The new Waterpods will incorporate a modified sensor, which is capable of in-situ sand/silt/clay fractional determination, while at the same time monitoring suspended and settleable solids. A newly designed floating hull system will also be deployed.

CONCLUSIONS

Placer mining is an important Yukon industry which must be sustained in a world of increasingly difficult environmental constraints. It is therefore important to have adequate relevant baseline data, which in the case of placer deposits is information on the types of sediment mined and the water quality before, during, and after mining. It is also important to have accurate, state of the art technology for monitoring and regulating mining activity, whether to meet regulatory standards or to achieve mine planning goals.

New equipment and technology allows field measurement of suspended solids concentrations of up to 20,000 mg/L. These measurements in conjunction with their corresponding sand/silt/clay fractional analysis will allow the prediction of settleable solids values as set out in the Yukon Placer Authorization. This will be important for the review of the 2001 YPA standards.

In addition, the careful analysis of grain size information and background water quality data collected from areas with no active mining could be compared to data collected from active placer operations. This would provide the potential to forecast the impact of placer mining on a virgin area.

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[1] Laboratory analysis of three *identically* coloured solutions, each having the same suspended solids concentration but one made from sand, one made from silt, and one made from clay, displayed different turbidity values when measured with standard lab turbidity instrumentation. The turbidity of the solution made from pure silt was 100% higher than that of the solution made from pure sand, while the turbidity of the solution made from pure clay was 150% higher than the solution made from the silt.

[2] Laboratory analysis of *different* coloured solutions, each having the same suspended solids concentration and created from sediment of the same particle size (i.e., silt only), displayed different turbidity values when measured with standard lab turbidity instrumentation. The turbidity of darker coloured solutions generally was higher than that of lighter coloured solutions.

REFERENCES

Bostock, H.S., 1966. Notes on glaciation in central Yukon Territory. Geological Survey of Canada. Paper 65-36, 18 p.

Cairnes, D.D., 1915. Exploration in Southwestern Yukon. *In:* Summary Report of the Geological Survey, Department of Mines, 1914, GSC Sessional Paper no. 26, p. 10-28.

Folk, R.L., 1974. Petrology of sedimentary rocks. Hemphill Publishing Co., Austin, Texas, 182 p.

Foscolos, A.E., Rutter, N.W. and Hughes, O.L., 1977. The use of pedological studies in interpreting the Quaternary history of central Yukon Territory. Geological Survey of Canada, Bulletin 271, 48 p.

Giles, T.R., 1993. Quaternary sedimentology and stratigraphy of the Mayo Region, Yukon Territory. Unpublished MSc. thesis, Department of Geology, University of Alberta, Edmonton, Alberta, 206 p.

Hammer, Mark J. and Hammer, Mark J. Jr., 1996. Water and Wastewater Technology Third Edition. Prentice-Hall Inc., New Jersey.

Hughes O.L., 1982. Surficial geology and geomorphology, Mayo map area. Geological Survey of Canada, Maps 2, 3, 4, 5-1982, 1:100 000 scale.

Hughes, O.L., 1987. Quaternary Geology. *In:* Guidebook to Quaternary Research in Yukon, S.R Morison and C.A.S. Smith (eds.), XII INQUA Congress, Ottawa, Canada. National Research Council of Canada, Ottawa, p. 12-16.

LeBarge, W.P., 1993. Sedimentology of placer gravels near Mt. Nansen, central Yukon Territory. Unpublished M.Sc. thesis, University of Calgary, Calgary, Alberta, 272 p.

LeBarge, W.P., 1995. Sedimentology of placer gravels near Mount Nansen, central Yukon Territory. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, Bulletin 4, 155 p.

LeBarge, W.P., 1996. Sedimentology and stratigraphy of Duncan Creek placer deposits, Mayo, central Yukon. *In:* Yukon Quaternary Geology, vol. 1, W.P. LeBarge (ed.), Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 63-72.

LeBarge, W, Bond, J., Hein, F. and Weston, L. (in prep.) Placer geology of Mayo area, central Yukon. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, bulletin with six 1:50 000 scale surficial geological maps.

Mining Inspection Division 1992-1997. Historical water analysis data from individual grab samples. Unpublished data, Mining Inspection Division, Yukon, Indian and Northern Affairs Canada.

Mining Inspection Division, 1993 (revised July 1998). Yukon placer authorization and supporting documents. Mining Inspection Division, Yukon, Indian and Northern Affairs Canada.

Okanagan University Technical Access Centre, 1998. Suspended sediment instrumentation research survey. Unpublished report prepared for Mining Inspection Division, Yukon, Indian and Northern Affairs Canada, 25 p.

Pentz, S., Smith, S., Kostaschuk, R. and Venditti, J., 1996. Effect of placer mining on suspended sediment in South McQuesten and McQuesten Rivers. Mining Inspection Division, Yukon, Indian and Northern Affairs Canada, 37 p.

Weston, L. (in prep.) Sedimentology and stratigraphy of Haggart Creek placer deposits, MSc. thesis, University of Calgary, Calgary, Alberta.

Brewery Creek gold deposit, central Yukon

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Viceroy Resources, Ltd.[1]

Diment, R. and Craig, S., 1999. Brewery Creek gold deposit, central Yukon. *In:* Yukon Exploration and Geology 1998, C.F. Roots and D.S. Emond (eds.), Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 225-230.

ABSTRACT

The Brewery Creek mine is a bulk tonnage gold deposit located 57 km east of Dawson City, in central Yukon, within the foothills of the Ogilvie Mountains along the northeastern boundary of the Tintina Trench. High-level fracture-controlled gold mineralization is hosted within Cretaceous monzonite sills and Devonian Earn Group siliciclastic rocks of the Selwyn Basin. Structural controls include northeast and southeast sub-vertical shears bounded by moderately south-dipping, southeasterly-extending listric normal faults; listric faulting and sill emplacements are localized along pre-existing graphitic thrust faults. Gold occurs as sub-micron particles in solid solution with pyrite and arsenopyrite as growth bands around larger sulphide grains that are disseminated within fine quartz veinlets. The open-pit heap leach operation produces 75,000 - 80,000 ounces annually, with a stripping ratio of 1.5:1 and a cash cost of US$200/oz or less. The mineable reserves at the end of 1997 stood at 13.3 MT @ 1.44 gpt (613,000 oz).

RÉSUMÉ

Située à 57 km à l'est de la ville de Dawson (Yukon), la mine Brewery Creek exploite un gisement d'or à fort tonnage dans le piedmont des monts Ogilvie, le long de la limite nord-est du sillon de Tintina. Une minéralisation peu profonde, contrôlée par des fractures, est encaissée dans des filons-couches de monzonite du Crétacé et des roches silicidastiques du groupe dévonien d'Earn du bassin de Selwyn. Les contrôles structuraux incluent des cisaillements sub-verticaux orientés nord-est et sud-est qui sont limités par des failles courbes normales de direction sud-est de pendage modéré vers le sud; les failles courbes et les emplacements des filons-couches se situent le long de failles graphitiques chevauchantes pré-existantes. L'or prend la forme de particules de moins d'un micron, en solution solide avec de la pyrite et de l'arsénopyrite dans des bandes d'accroissement autour de grains de sulfure plus grossiers qui sont disséminés dans de fines veinules de quartz. L'exploitation à ciel ouvert utilisant la lixiviation en tas produit de 75 000 à 80 000 onces (plus de 2 millions de grammes) d'or par année à un coefficient de recouvrement de 1,5/1 et à un coût au comptant de 200 $ US l'once ou moins. Les réserves exploitables s'élevaient à 13,3 Mt renfermant 1,44 g/t (613 000 onces ou 17,4 millions de grammes) à la fin de 1997.

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[1] *Viceroy Resources, Ltd., phone (867) 393-6500, fax (867)-393-6503*

INTRODUCTION

The property consists of 803 contiguous quartz claims and mining leases covering 12,975 hectares and is owned and operated by Viceroy Minerals Corporation, a subsidiary of Viceroy Resource Corporation.

Brewery Creek is a bulk tonnage gold deposit located 57 km due east of Dawson City. Noranda Exploration Co. Ltd. discovered the property in 1987, using soil geochemistry, and outlined reserves in eight zones extending over a strike length of 12 km (Fig. 1). Loki Gold Corporation optioned the property in 1990 and obtained a 100% interest in 1993. Following two years of development work and an extensive environmental review, Loki obtained a water license in August, 1995 and began construction of the heap leach pad and facilities. Loki merged with Viceroy Resource Corporation in May, 1996 and realized first gold production in November. Commercial production was reached in May, 1997. At December 31, 1997, mineable reserves on the property were 13.3 million tonnes @ 1.44 gpt gold (613,000 contained ounces) which is accessible by open pit with a stripping ratio of 1.5:1.

REGIONAL GEOLOGY

The Brewery Creek property is located in the foothills of the Ogilvie Mountains along the northeastern boundary of the Tintina Trench. This major topographic feature, the northwestern extension of the Rocky Mountain Trench, marks the trace of a dextral strike-slip fault system with an apparent offset of as much as 450 km (Gabrielse and Yorath, 1991). At this latitude, the Tintina Fault juxtaposes late Proterozoic and Paleozoic rocks of the Selwyn Basin to the northeast, against sheared, metamorphosed rocks of the Yukon-Tanana Terrane, to the southwest.

The property covers an area of clastic sedimentary rocks of the Cambrian to Lower Devonian Road River Group and the Devono-Mississippian Earn Group. Due to poor exposure, Earn Group rocks were not previously recognized in this area. Quartzite and argillite of the Late Proterozoic-Early Cambrian Hyland Group are exposed several kilometres west and north of the property. All of these rocks lie in the hanging wall of the south-dipping Robert Service Thrust, and are cut by stocks, dykes and sills ranging in composition from diorite to quartz

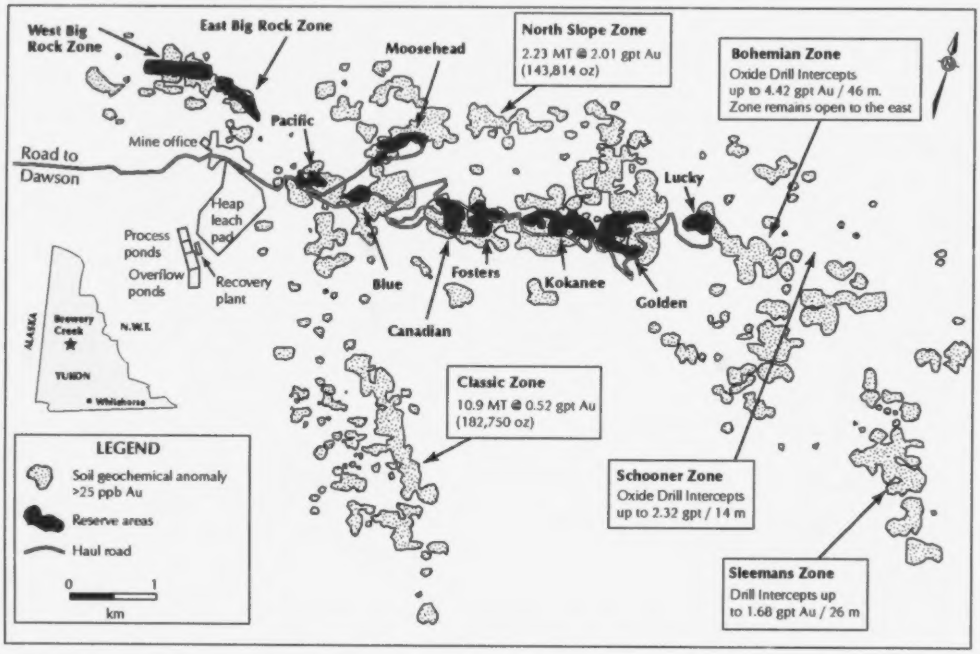
West Big Rock Zone
East Big Rock Zone
Moosehead
North Slope Zone
2.23 MT @ 2.01 gpt Au
(143,814 oz)
Bohemian Zone
Oxide Drill Intercepts
up to 4.42 gpt Au / 46 m.
Zone remains open to the east
Pacific
Mine office
Road to Dawson
Heap leach pad
Process ponds
Overflow ponds
Recovery plant
Lucky
Blue
Fosters
Kokanee
Golden
Canadian
ALASKA
Brewery Creek
N.W.T.
YUKON
Whitehorse
Classic Zone
10.9 MT @ 0.52 gpt Au
(182,750 oz)
Schooner Zone
Oxide Drill Intercepts
up to 2.32 gpt / 14 m
Sleemans Zone
Drill Intercepts up
to 1.68 gpt Au / 26 m
LEGEND
Soil geochemical anomaly >25 ppb Au
Reserve areas
Haul road
0
1
km

Figure 1. Exploration potential and current reserves for the Brewery Creek mine.

monzonite and syenite. The intrusive rocks belong to the Tombstone Plutonic Suite of mid-Cretaceous age.

This part of northern Yukon escaped continental glaciation during the most recent (McConnell) ice advance, allowing a zone of deep weathering and oxidation to be preserved. The oxidation zone extends locally to depths of more than 100 m. Another consequence of the lack of glaciation is that there are no till sheets to mask the geochemical response, and transport of geochemical anomalies is generally restricted to down-slope creep. Some areas of the property have a cover of "loess" (windblown glacial silt or rock flour admixed with coarser material of local derivation) which may reach thicknesses of almost 20 m locally (J.R. Allan, pers. comm., October, 1995). This has the effect of masking portions of geochemical patterns.

PROPERTY GEOLOGY

The following description of the geology of the Brewery Creek property is derived largely from Diment (1995) and from an unpublished map prepared by Loki, based on the work of Bremner (1993-1995). Other information sources are cited as appropriate.

STRATIGRAPHY

Two major packages of dominantly clastic sedimentary rocks are recognized at Brewery Creek (Bremner, 1993-1994, Diment, 1995). These rocks have been correlated with major packages within the Selwyn Basin stratigraphy, the Road River and Earn groups.

The older strata, exposed on the northern portion of the property and generally lying north and south of the known mineralized zones, are correlated with the Road River Group. In the Nahanni map area to the southeast, this group was subdivided by Gordey and Anderson (1993) into the lower Duo Lake Formation of black siliceous graptolitic shale and chert overlain by the Steel Formation of orange-weathering mudstone. At Brewery Creek, the Steel Formation consists of tan-weathering, wispy-laminated, "burrowed" siltstones, with beds up to 10 m thick of graphitic shale and chert. These rocks overlie massive black chert of the Duo Lake Formation and calcareous andesitic flows, tuffs and breccias which are probably Late Cambrian or Early Ordovician in age, similar to the Menzie Creek volcanic rocks at Faro. A conglomerate unit deposited at the top of the volcanic sequence consists of rounded fragments of volcanic rock in a tuffaceous or calcareous matrix. The top of the Road River succession was defined by Gordey and Anderson (1993) in the Nahanni map-area as the highest occurrence of wispy-laminated siltstone; the same criterion has been used at Brewery Creek.

The contact between the Road River and Earn groups is marked by a regional unconformity (Murphy and Héon, 1994). At Brewery Creek, the Earn Group strata make up a heterogeneous package of siliciclastic rocks including argillite, silty shale, sandstone, greywacke and debris flow conglomerate overlain by a distinctive sequence of tuffaceous sandstone and shale. Volumetrically minor units include limestone, bedded barite and black graphitic argillite.

STRUCTURE

The stratified rocks generally strike northwest and dip moderately southeast. A few northerly dips show the presence of open south-vergent, upright folds in the higher units of the Earn Group stratigraphy. Fold axes trend about 100° and plunge gently (about 10°) to the east. A well-developed slaty cleavage occurs in finer-grained clastic rocks. Local tight folds in Earn Group rocks probably reflect deformation related to thrust faulting and drag on normal faults.

The most important structures at Brewery Creek are imbricate low angle faults which strike generally west-northwest and dip to the south. Based on the stratigraphic relationships, these are inferred to be thrust faults. They appear to have controlled the emplacement of Cretaceous quartz monzonite sills which host most of the gold mineralization. Later dip-slip movement of the faults is recorded by slickensides and rotation of some of the sills and adjacent sedimentary rocks on curved fault surfaces, as well as the development of downward-stepping contacts and extensional fault wedges.

Shear zones with a prominent north-northeast (20° to 40°) vertical fracture cleavage cut the sills and sedimentary rocks overlying the thrust faults. Intense brecciation and silicification is associated with these shear zones, and in places they have been invaded by quartz monzonite dykes. The shear zones appear to terminate downward at the thrust surface, and may result from tear faulting contemporaneous with the thrusts. The relationship between the low angle faults, shear zones and quartz monzonite sills suggests that the intrusions are probably syntectonic, formed during an episode of Cretaceous deformation.

Other sets of subvertical fracture cleavages strike about 100° and 340° and are also mineralized. Both the 40° and 100° fracture sets show evidence of normal displacement in the form of steeply plunging slickensides, and offsets up to 3 m. However, numerous subhorizontal slickensides suggest a significant component of strike slip motion.

The latest stage of faulting on the property involves unhealed structures. A north-northwest set consists of faults interpreted as steeply dipping reverse or normal faults, which may have displaced stratigraphic units by as much as 50 m. A second set strikes east-northeast and appears to have accommodated left-lateral displacement up to 200 m. Both sets of faults truncate sulphide mineralization and all previously described structures.

INTRUSIVE ROCKS

Several distinct intrusive rock types are present at Brewery Creek. The most important bodies from an economic point of view are semi-conformable sills of quartz monzonite, intrusive into the upper Road River and lower Earn Group strata. These sills, which yielded a zircon age of 91.4 +/- 0.2 Ma (Diment, 1995), have been exposed over a strike length of at least 12 km. Where cut by faults or shear zones, they show evidence of gold mineralization over most of this distance. They appear to have been emplaced along Cretaceous thrust faults, mostly marked by zones of graphitic argillite; hornfels development is minimal, suggesting emplacement at a shallow depth. The sills range in thickness from 5 to 10 m or less in the western portion of the property, to greater than 100 m in the east.

In the south-central portion of the property, stocks of syenite and biotite monzonite, as well as sills of the latter rock, have intruded tuffaceous shale, sandstone and chert of the Earn Group. These intrusive rocks tend to be relatively coarse-grained and equigranular, with well-developed hornfels aureoles. With the exception of the Classic Zone, they appear to be unmineralized.

MINERALIZED ZONES

There are at present nine ore zones (or groups of zones) in the mineable reserve category, one zone presently being taken from resource to mineable reserve, two zones with geological resources and an additional two zones which remain exploration targets (Fig. 1). Seven of the ore zones are distributed along a general easterly (mine grid) trend; the eight and ninth lie to the north of this trend. From west to east along the trend, the zones are: Pacific, Blue, Canadian (and west Canadian), Fosters (upper and lower), Kokanee, Golden (upper and lower) and Lucky. The Moosehead Zone lies grid northeast of the Blue Zone, while the Big Rock Zone lies northwest of the Pacific Zone. Southeastward along the main trend is the Bohemian Zone, with a geological resource currently being brought into reserve. The structurally unique Classic and North Slope zones, with defined geological resources, lie just over 3 km south of the Blue and one kilometre north of the Kokanee, respectively. The Schooner and Sleemans zones, along strike to the southeast from the Bohemian Zone, remain priority exploration targets. The total distance between the occurrences at either end of the main trend is almost 12 km.

MINERALIZATION AND ALTERATION

ALTERATION

Alteration associated with the mineralized zones at Brewery Creek follows the major structures. Pervasive phyllic alteration predominates, and is best developed in the intrusive rocks. Altered rocks are characterized by destruction of mafic phenocrysts, alteration of feldspars to sericite (illite) and kaolinite, and introduction of secondary quartz with fine-grained pyrite and arsenopyrite. Intense kaolinization and silicification is localized in narrow vertical shear zones and is associated with high gold grades. A weak propylitic halo, characterized by chloritization of mafic phenocrysts and strong carbonatization, commonly occurs peripheral to mineralized zones.

Alteration, sulphide distribution and gold mineralization all appear to be lithologically controlled. Those units which deformed in a brittle fashion, such as intrusive rocks, sandstone and siltstone, tend to be more strongly altered, due to fault-induced permeability. Shale and argillite tended to deform plastically and are much less altered and mineralized.

MINERALOGY

Mineralogy at Brewery Creek appears to be very simple. Below the zone of weathering, fine-grained pyrite, arsenopyrite and some marcasite are disseminated within quartz veinlets and areas of pervasive silicification. Ion microprobe studies at the University of Western Ontario (Chryssoulis and Agha, 1990) on selected samples showed that gold occurs primarily as extremely fine (micron-sized) particles or as "solid solutions" in arsenopyrite and pyrite growth bands around larger sulphide grains. The sulphide grains themselves are generally less than 250 microns in diameter. Other sulphide minerals noted by Chryssoulis and Agha (1990) included trace amounts of chalcopyrite, sphalerite and pyrrhotite.

Within the zone of weathering, which is extensive and reaches an average depth of 50 m, sulphides have in general been converted to goethite ($Fe_2O_3 \cdot H_2O$) and scorodite. Coarse-grained stibnite veins are commonly preserved. The stibnite veins appear to post-date the main period of mineralization, and rarely contain significant gold values.

STRUCTURAL CONTROLS

The primary control of sill emplacement and gold mineralization seems to be a series of imbricate east to east-southeast trending thrust faults, which have been traced for more than 12 km and probably extend further in each direction. In a few cases, the faults crosscut stratigraphy. The faults juxtapose brittle coarse clastic intrusive rocks against underlying graphitic argillite. They are associated with parallel zones of mineralization which dip 5° to 60° south in the fractured and altered hanging wall rocks. Mineralized zones are contained within altered and fractured rocks lying above the faults and the footwall argillite is generally barren.

A further control on gold mineralization appears to have been exerted by subvertical west-northwest and north-northeast shears in the hanging wall rocks. These fractures are generally filled by narrow (less than 1 centimetre) en echelon quartz veinlets containing fine disseminated sulphides. Locally, as in the Golden Zone bulk sample trench, such fractures coalesce into quartz breccia zones up to several metres wide. These mineralized structures are not generally traceable into the footwall rocks.

In the case of the Classic Zone, low-grade gold mineralization is hosted by a small hornblende monzonite stock 3 km south of the main trend of ore bodies along a northwest-trending normal fault. A strong arsenic soil anomaly follows the trend of this structure for about 3 km northwest to the Pacific Zone. The significance of this structure and its mineralization are as yet unknown and require further exploration.

LITHOLOGIC CONTROLS

Eighty-five percent of the known gold mineralization at Brewery Creek is contained within altered quartz monzonite. Biotite monzonite and syenite are hosts for gold mineralization at the presently under-explored Classic Zone, where the intrusive rocks form stocks rather than sills or dykes. Whole-rock analyses of intrusive rocks suggest a positive correlation between gold content and alteration, characterized by consistent sodium and potassium depletions and silica enrichment in the mineralized zones, except in the case of the Classic Zone, where high potassium levels are reported.

Only the Pacific, Blue and Moosehead zones contain significant amounts of gold mineralization in sedimentary rocks. Here, sandstone and shale have been pervasively flooded by silica, and en echelon hairline quartz veinlets, commonly with envelopes of montmorillonite, occur along bedding planes. Sulphides, especially arsenopyrite, are finely disseminated in unweathered rocks, up to as much as 15% in places.

In the North Slope Zone, calcareous, Steel Formation siltstone of the Upper Road River Group has been altered and cut by a fine quartz stockwork. Bleached sericite haloes have formed around the more siliceous zones; pyrite occurs on fracture surfaces and along bedding planes. The Steel Formation has striking similarities to the highly productive Roberts Mountain formation in the Carlin Trend and may represent a favourable host for replacement-style mineralization.

Argillite, the most common rock type in most of the zones, is generally unmineralized. Elevated gold contents are in most cases confined to highly sheared graphitic contacts between argillite and overlying mineralized intrusive rock or coarser clastic lithologies.

"PREG-ROBBING" ROCKS

Some of the shales and argillites at Brewery Creek have the tendency to remove gold from the pregnant solutions in a heap leach environment and fix it so that it cannot be dissolved and recovered. Numerous tests have been performed on samples of both argillite and graphitic argillite, from surface exposures and drill holes, in order to investigate this problem.

Lenses of potentially "preg-robbing" argillite occur either below or within mineralized zones. The purpose of the testing was to examine the magnitude of the potential problem, and to estimate how much, if any, selective mining might be required. The results of the tests showed that there is a strong correlation between "preg-robbing" tendencies and both the oxide/sulphide interface and the position of the paleo-water table boundary, leading to the following conclusions.

1. Within the oxide zones of the deposits (i.e., areas with significant limonite content and an absence of visible sulphides) above the paleo-water table, argillite (whether obviously graphitic or not) does not have "preg-robbing" characteristics. Neither the percentage of visible graphite nor its morphology (even where described as massive, "sooty" graphite) appears to have any effect on leach rate or gold recovery.
2. Within the oxidized portions of the deposit lying below the paleo-water table, argillites may be weakly to moderately "preg-robbing."
3. Within the "transition zone," where both limonite and sulphides are noted, argillite is commonly weakly "preg-robbing" if lying above the paleo-water table and is moderately to strongly "preg-robbing" if lying below.
4. Within the sulphide zones of the deposits (i.e., in areas with > 1% sulphides and an absence of visible limonite), argillites are strongly "preg-robbing."

Surprisingly, there appears to be no recognizable correlation between graphite content of argillite and the degree of "preg-robbing" characteristics.

AGE AND CLASSIFICATION OF DEPOSITS

Diment (1995) described the Brewery Creek deposit as a member of the "adularia-sericite" class of epithermal precious metal deposits, as described by Heald et al. (1987). This classification of Brewery Creek appears to have been based on several factors, perhaps the most important being the generally low concentrations of sulphides and the typical chemical signature of gold, silver, arsenic, antimony, mercury and barium. As with other adularia-sericite type deposits, gold mineralization does not appear to be confined to one rock host rock type.

The mineralization must be mid-Cretaceous or younger, based on its spatial relationship to brittle faults cutting the Cretaceous intrusions. Several quartz monzonite dykes have invaded steep shear zones which cut quartz monzonite sills in the same area, providing evidence of late magmatic activity which could be related to the gold mineralization.

RECENT DEVELOPMENTS IN EXPLORATION

Recent exploration in the North Slope Zone has discovered the presence of decalcification and silica replacement in stratigraphically lower Silurian Road River Group sediments suggesting that a Carlin-type model may be appropriate at Brewery Creek. A resource of 2.2 million tonnes of 2.01 gpt gold (142,000 oz) has been defined in this zone. The narrow-erratic sediment-hosted mineralization remains open along strike.

A north-northwest striking subvertical extensional fault hosts low-grade gold mineralization (0.3 to 0.6 gpt) gold along a 500 metre strike length in the Classic Zone. Gold is confined to centimetre scale en echelon quartz veinlets which parallel this structural trend cutting biotite monzonite and syenite stocks. An oxide resource of 10.9 million tonnes of 0.52 gpt gold (182,000 oz) using a cut-off of 0.25 gpt gold has been defined. Bottle roll results have returned up to 67% recovery at depths greater than 150 m.

The Bohemian Zone is open along strike to the east and southwest along high angle east southeast and north northeast structures. An oxide resource of 1.3 million tonnes of 1.6 gpt gold (65,733 oz) based upon drilling up to July, 1998, has been defined. This resource includes drill intercepts up to 4.42 gpt gold over 46 m in oxidized quartz monzonite. The resource is being updated to incorporate 3 additional phases of infill and step-out drilling at the time this paper went to press.

MINE OPERATIONS

The Brewery Creek mine achieved commercial production in May, 1997. During 1997, a total of 72,387 ounces were produced from the Kokanee and Golden zones, at a cash cost of US$184 per ounce. A total of 2.1 million tonnes of ore were mined and 2 million tonnes of ore with an average grade of 1.87 gpt gold were delivered to the leach pad.

For the nine months ending September 30, 1998, a total of 52,638 ounces of gold were produced at a cash operating cost of US$197 per ounce. A total of 2.3 million tonnes of ore grading 1.46 gpt gold were mined and 2.2 million tonnes of ore grading 1.46 gpt gold were delivered to the leach pad. Ore was mined from the Kokanee and Golden pits. An intermediate leaching circuit was commissioned at the Brewery Creek mine which effectively doubles the amount of ore under leach. Production forecast for 1998 for Brewery Creek is 80,000 ounces.

REFERENCES

Bremner, T., 1993-94. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs, Canada. Unpublished geological map of Brewery Creek, Yukon, 1:10 000 scale.

Chryssoulis, S.L. and Agha, U., 1990. Gold process mineralogy of select samples from Brewery Creek Y.T., University of Western Ontario, London, Ontario.

Diment, R., 1995. Brewery Creek project. Loki Gold Corporation. Assessment Report, Mineral Resources Directorate, Yukon, Indian and Northern Affairs Canada.

Gabrielse, H. and Yorath, C.J., 1991. Geology of the Cordilleran Orogen in Canada. Geological Survey of Canada, Geology of Canada, No. 4.

Gordey, S.P. and Anderson, R.G., 1993. Geology of the Northern Cordilleran Miogeocline, Nahanni map area (105-I), Yukon and Northwest Territories. Geological Survey of Canada, Memoir 428.

Heald, P., Foley, N. and Hayba, D., 1987. Comparative anatomy of volcanic-hosted epithermal deposits; acid-sulphate and adularia-sericite types. Bulletin of the Society of Economic Geologists, vol. 82, No. 1, January-February, 1987.

Murphy, D.C. and Héon, D., 1994. Geological overview of Sprague Creek map area, Western Selwyn Basin. *In:* Yukon Exploration and Geology 1993, Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 29-46.

A summary report on the geology of the Brown-McDade gold-silver deposit, Mount Nansen mine area, Yukon

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Stroshein, R., 1999. A summary report on the geology of the Brown-McDade gold-silver deposit, Mount Nansen mine area, Yukon. *In:* Yukon Exploration and Geology 1998, C.F. Roots and D.S. Emond (eds.), Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 231-236.

ABSTRACT

The Brown-McDade deposit was the first vein system discovered in the Mount Nansen camp and has produced approximately 34,000 ounces (1058 kg) of gold and 131,000 ounces (4,075 kg) of silver from 225,000 metric tonnes of ore since production began in November, 1996. Production rates have varied since the mill start-up but the carbon-in-leach (CIL) plant is currently operating near capacity at 700 metric tonnes per day.

Mining at the Brown-McDade open pit has exposed two separate and distinct deposit types. The first type is gold-silver vein mineralization hosted by a massive feldspar porphyry dyke. These fine-grained quartz-sulphide veins and vein breccia are enclosed by silicified and/or intensely clay-altered brecciated feldspar porphyry. The feldspar porphyry dyke has intruded along an igneous-metamorphic contact that has been mined over a strike length of 50 m in the southern portion of the pit. The second deposit type that occurs at the north end of the pit consists of a siliceous, sulphide-rich breccia in a pipe-like structure hosted by metamorphosed carbonate and clastic rocks of the Nasina Assemblage. The pipe is elongate in plan with a high-grade core approximately 15 m wide and 25 m long surrounded by a low-grade envelope consisting of quartz-sulphide stringers in a silicified breccia. The deposits are separated by a northeast-striking fault which truncates and offsets the main vein-dyke mineralization.

The ore is composed of fine-grained quartz and sulphides in narrow veins or as matrix to a breccia of silicified and pyritized wall rock fragments. Unoxidized ore contains dark grey silica and pyrite, arsenopyrite, sphalerite, galena, sulphosalts, bornite, stibnite and chalcopyrite. Gold is genetically related to the pyrite phase of the mineralization and occurs as 5 to 50 micron-sized inclusions in pyrite grains. Oxidation of sulphide minerals extends to depths of up to 70 m and a large portion of the gold grains have been exposed by oxidation of the sulphides and post-depositional cataclastic fractures in the pyrite. The silver mineralogy is not as well understood but appears to be related to the base metal sulphide mineralization.

RÉSUMÉ

Le gisement Brown-McDade, le premier réseau filonien découvert au camp Mount Nansen, a fourni approximativement 34 000 onces (1058 kg) d'or et 131 000 onces (4075 kg) d'argent extraits de 225 000 tonnes de minerai depuis les débuts de la production en novembre 1996. Le taux de production a varié depuis la mise en exploitation de l'usine, mais celle-ci est actuellement exploitée presque à sa pleine capacité de 700 tonnes par jour.

L'extraction de la fosse à ciel ouvert Brown-McDade a mis à nu deux types distincts et séparés de gisements. Les gisements du premier type sont des minéralisations en or et argent de type filonien dans un dyke de porphyre feldspathique massif et sont composés de filons de quartz et sulfures à grains fins et de brèche filonienne compris dans un porphyre feldspathique bréchique silicifié et/ou fortement argillisé. Le dyke de porphyre feldspathique a pénétré le long d'un contact entre roches ignées et métamorphiques que l'extraction a permis de suivre sur 350 mètres dans la partie sud de la fosse. Les gisements du deuxième type, à l'extrémité nord de la fosse, consistent en brèche siliceuse riche en sulfures dans une structure en forme de cheminée qui est encaissée dans des roches carbonatées et clastiques métamorphisées de l'assemblage Nasina. La cheminée présente en plan une forme allongée avec une partie centrale à teneur élevée mesurant approximativement 15 mètres de largeur sur 20 mètres de longueur et elle est entourée d'une enveloppe à faible teneur consistant en petits filons de quartz et sulfures dans une brèche silicifiée. Les gisements sont séparés par une faille orientée nord-est qui tronque et déporte la minéralisation filonienne-dyke principale.

Le minerai se compose de quartz avec sulfures de granulométrie fine dans des filons étroits ou prend la forme de gangue bréchique avec fragments de roche encaissante silicifiés et pyritisés. Le minerai non oxydé renferme de la silice gris foncé et des sulfures, notamment de la pyrite, de l'arsénopyrite, de la sphalérite, de la galène, des sulphosels, de la bornite, de la stibine et de la chalcopyrite. L'or est génétiquement relié à la phase pyrite de la minéralisation et prend la forme d'inclusions de 5 à 50 microns dans les grains de pyrite. Les minéraux sulfurés sont oxydés jusqu'à des profondeurs atteignant 70 mètres et une grande partie des grains d'or ont été mis à nu par oxydation des sulfures et par des fractures cataclastiques post dépôt dans la pyrite. La minéralogie de l'argent n'est pas aussi bien comprise mais semble reliée à la minéralisation en sulfures de métaux communs.

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INTRODUCTION

The Brown-McDade gold-silver deposit is located approximately 60 km along the Mount Nansen road west of Carmacks, south-central Yukon (Fig. 1). The deposit was discovered by prospectors Afe Brown and George McDade in 1943. The mineralization was explored underground in 1946 with approximately 750 m of drift and crosscut development. The deposit was explored intermittently by trenching, percussion drilling (17 holes, 1285 m) and surface diamond drilling (86 holes, 6535 m) between 1984 and the time of development of the open-pit mine in November, 1996.

BYG Natural Resources Inc. operates a 700-metric tonne-per-day carbon-in-leach (CIL) mill at the Mount Nansen site that has produced approximately 34,000 ounces (1058 Kg) of gold and 131,000 ounces (4075 Kg) of silver from 225,000 tonnes of ore. Past production has been from the Webber and Huestis veins in 1968-69 while all the current production has been from the Brown-McDade deposit (Fig. 2). Future production will be from underground on the lower Brown-McDade veins and breccia pipe as well as the Flex and other gold-silver rich zones on the property including the Webber and Huestis veins.

Mining of the Brown-McDade deposit has provided a detailed geological look at the deposit that has resulted in a revised exploration model for the deposit and other occurrences in the area.

REGIONAL GEOLOGY

The Brown-McDade gold-silver deposit in the Mount Nansen mine area is located in the Dawson Range within Yukon-Tanana Terrane (YTT). The YTT Early Mississippian metamorphic rocks are intruded by several plutonic suites (Carlson, 1987).

The metamorphic rocks are separated into two suites, meta-sedimentary and meta-igneous. Micaceous quartz-feldspar gneiss, schist, and quartzite of the Nasina Assemblage form the meta-sedimentary rock suite. Metamorphosed carbonate rocks exposed in the open pit are the first to be recognized in the area. The meta-igneous package includes biotite-hornblende feldspar gneiss and coarse-grained granodiorite orthogneiss with lesser amphibolite.

The metamorphic rocks have been intruded by foliated Upper Triassic and weakly foliated Jurassic diorite, granodiorite, and syenite batholiths.

The metamorphic and foliated plutonic rocks are intruded by mid-Cretaceous felsic plutonic rocks of the Coffee Creek Plutonic Suite and capped by the coeval mafic to intermediate volcanic flow and tuff rocks of the Mount Nansen Volcanic Suite (Johnston and Mortensen, 1994). Genetically related sub-volcanic feldspar porphyry dykes and plugs intrude all rock types (Sawyer and Dickinson, 1976).

The Late Cretaceous Carmacks Volcanic Suite, although absent in the immediate Mount Nansen area is voluminous in the region where relatively flat lying pyroclastic tuffs and flow units form prominent ridges capping the metamorphic rocks (Carlson, 1987). The Carmacks Volcanic Suite is magmatically related to the Prospector Mountain Plutonic Suite (Johnston and Mortensen, 1994).

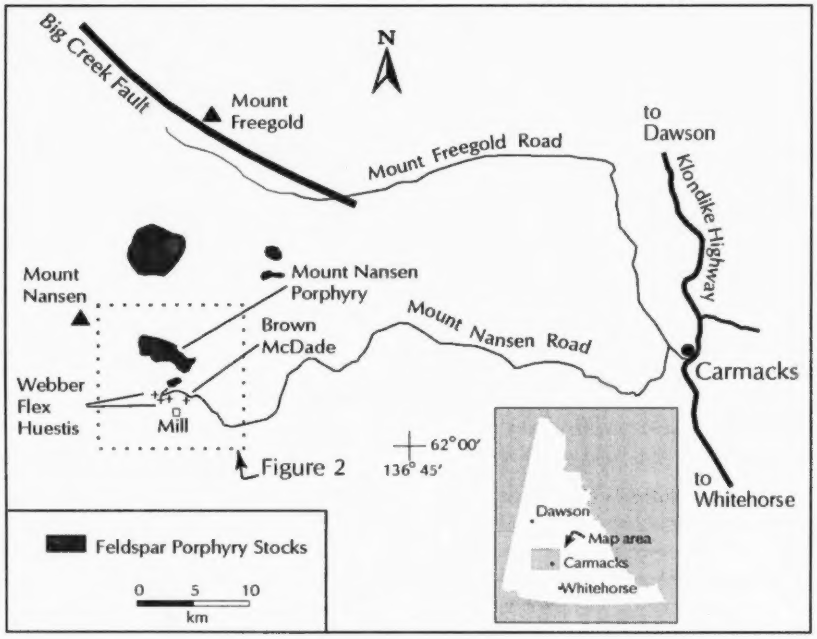

Figure 1. Location of veins (small crosses) in the Mount Nansen mine area.

MOUNT NANSEN GEOLOGICAL AND METALLOGENIC SETTING

In the centre of the Mount Nansen property, a sub-volcanic feldspar porphyry intrusive complex of the Mount Nansen Volcanic Suite forms an east-west elongate zone about 3.2 km long by 1.6 km wide (Fig. 2). The Mount Nansen porphyry complex hosts disseminated copper-molybdenum mineralization in a diverse assemblage of porphyritic rocks including dykes, small plugs and breccia bodies (Sawyer and Dickinson, 1976).

The precious metal mineralization on the Mount Nansen property consists of structurally controlled planar veins with associated clay-rich and bleached alteration zones and pipe-like breccia systems peripherial to the central Mount Nansen porphyry complex. The mineralized vein zones range from narrow, simple quartz-sulphide veins to complex, anastomosing and braided systems that crosscut all rock types. The veins tend to occupy fractures in metamorphic rocks (Huestsis-Flex-Webber) or invade porphyry dykes that preferentially intrude zones of structural weakness such as faults (Orloff King) or intrusive contacts (Brown-McDade). Several mineralized breccia bodies have been identified within the porphyry complex (1972 Breccia), in older plutonic rocks (1998 Breccia), and in competent metamorphic rocks (north end of Brown-McDade).

A widespread propylitic alteration zone around the Mount Nansen porphyry complex has affected most rocks on the property. Rocks in the vicinity of the Brown-McDade deposit

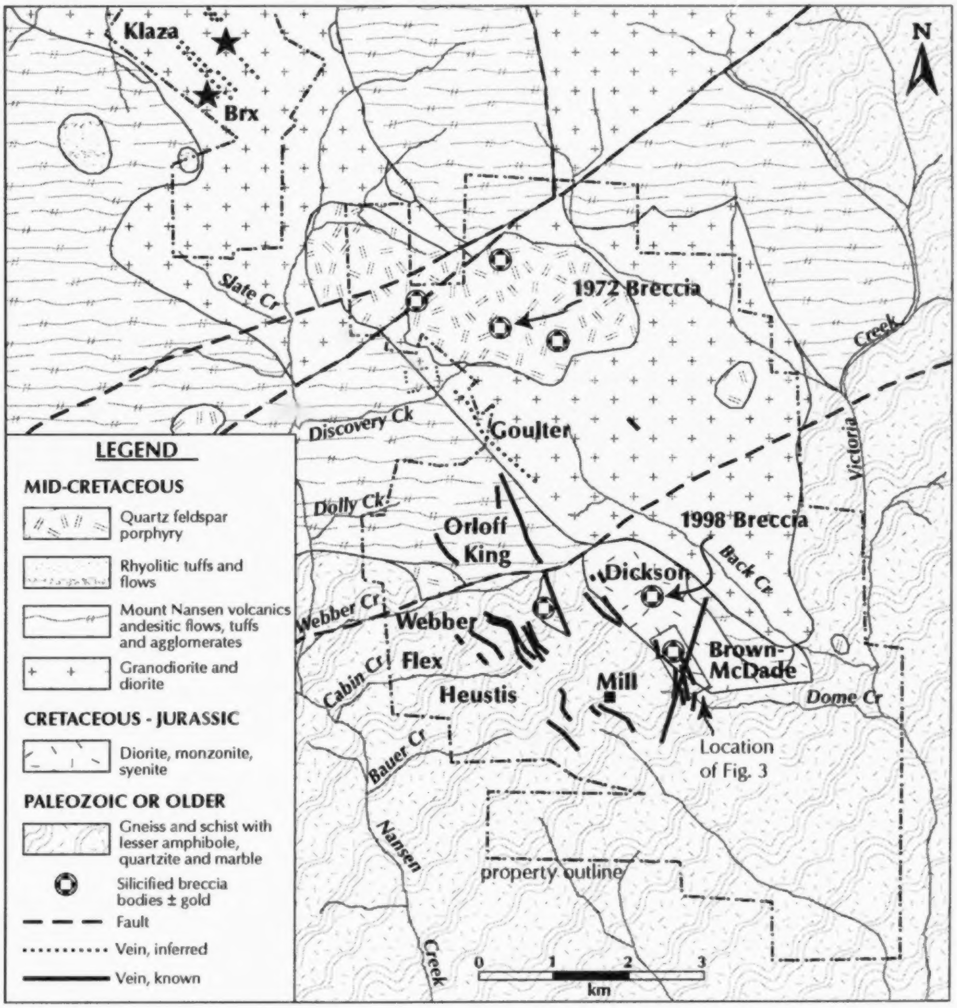
Klaza
Brx
N
Slate Cr
1972 Breccia
Creek
Victoria
Discovery Ck
Goulter
Dolly Ck
Orloff King
1998 Breccia
Back Cr
Dickson
Webber Cr
Webber
Flex
Cabin Cr
Heustis
Mill
Brown-McDade
Dome Cr
Location of Fig. 3
Bauer Cr
Nansen Creek
property outline
0 1 2 3
km
LEGEND
MID-CRETACEOUS
Quartz feldspar porphyry
Rhyolitic tuffs and flows
Mount Nansen volcanics andesitic flows, tuffs and agglomerates
Granodiorite and diorite
CRETACEOUS - JURASSIC
Diorite, monzonite, syenite
PALEOZOIC OR OLDER
Gneiss and schist with lesser amphibole, quartzite and marble
Silicified breccia bodies ± gold
Fault
Vein, inferred
Vein, known

***Figure** 2. Geology of the Mount Nansen area.*

contain epidote, calcite, pyrite and magnetite replacement of hornblende characteristic of the propylitic alteration mapped near the porphyry complex (Sawyer and Dickinson, 1976).

The Mount Nansen area was beyond the limit of the most recent continental glaciation although earlier incursions moved up the valley bottoms (Sawyer and Dickinson, 1976). Weathering extends to depths of up to 70 m below surface and includes leaching and oxidation in the mineralized zones. Sulphides are commonly altered to limonite or other oxides.

BROWN-MCDADE DEPOSIT GEOLOGY

The Brown-McDade open-pit mine encompasses two distinct deposits separated by a complex, steeply dipping, northeasterly trending fault zone which crosscuts the pit at an acute angle 30 to 40 m north of the underground adit (Fig. 3). The southern two-thirds (350 m) of the pit has been developed to exploit a complex vein system made of planar veins, vein breccias and mineralized and altered wallrock. The northern portion of the pit encompasses an elongate breccia zone 25 m wide by 70 m long with intensely mineralized internal pipe-like zones in the central portion.

The host rock for the planar vein system is a feldspar porphyry dyke that has intruded the contact between weakly foliated hornblende diorite of probable Jurassic age and metamorphic rocks of the Devono-Mississippian Nasina Assemblage. The vein-dyke-contact system trends north northwest and dips at 70° southwest. The vein-dyke complex is being mined along a 350 m strike length, currently 45 m below the original surface. The width of the dyke enclosing the vein system varies from several metres to greater than 30 m. On one section on the 1250 bench, four 2 m channel samples across the exposed dyke on the 1250 bench yielded an average grade of 21 g/t gold and 108 g/t silver. The 2 m wide vein mineralization of the interval assayed 51.6 g/t gold and 201 g/t silver. Thickening of the dyke and contained veins occurs with embayments in the footwall diorite contact (Fig. 3).

The vein-dyke system gradually diminishes in thickness at the south end of the deposit where the diorite-metamorphic contact turns eastward. The north end of the vein-dyke complex is truncated by a north northeasterly trending system of post-mineralization faults. The faults are interpreted to have left-lateral offsets consistent with observations at other localities on the property (Anderson and Stroshein, 1997). The sense of movement from the re-location of the footwall diorite to the hanging wall of the deposit suggests that the northern extension of the vein-dyke complex has been offset as much as 200 m to the southwest.

The sulphide-rich breccia-hosted deposit is located at the northern end of the open pit in the hanging wall of the north northeast trending, offsetting fault system. The gold-silver rich breccia mineralization (grades of 9-34 g/t gold and 25-90 g/t silver) forms an irregular pipe-like body elongate in plan, approximately 15 m wide by 25 m long. The pipe appears to plunge at a moderate to steep angle (50°-70°) towards the

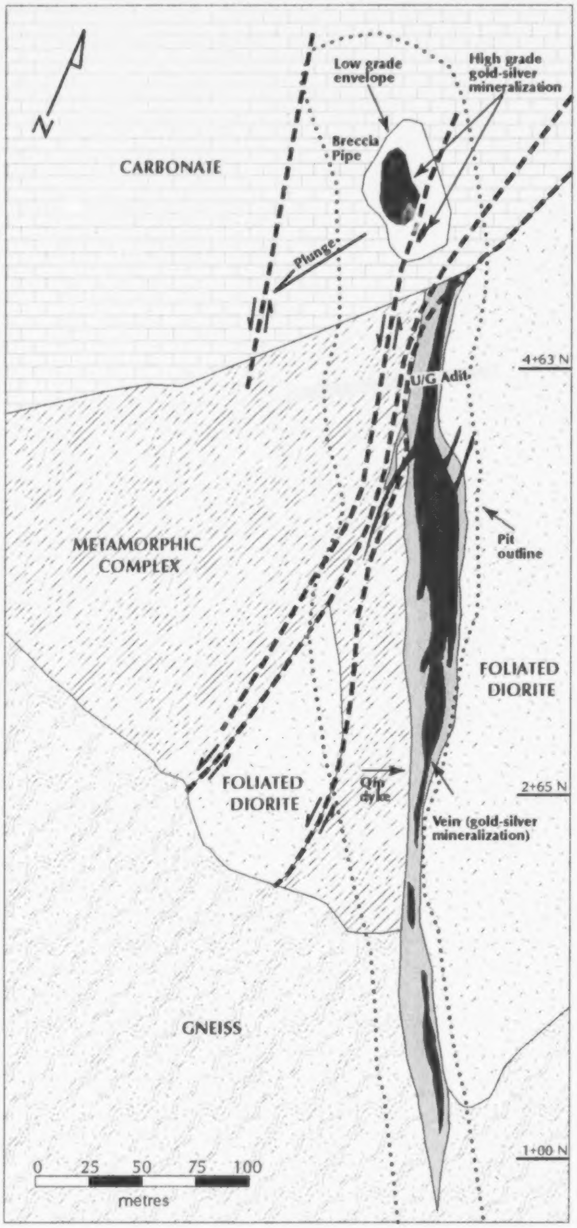

Figure 3. *Geology map of the Brown-McDade mine. The outline of the current open pit is indicated by a dotted line.*

southwest and is contained within a broader breccia envelope of low grade brecciated and weakly mineralized rock approximately 70 m long by 25 m wide. The host rock of the breccia pipe exposed in the pit is a re-crystallized limestone that is locally marble. A drill hole intersected the mineralization 60 m down plunge hosted by fine-grained metamorphosed clastic rocks (23.8 m grading 11.7 g/t gold and 24 g/t silver).

The unbrecciated limestone is massive and thick bedded, striking at 120° and dipping 40° to the north. Foliation of the metamorphic rocks strikes northwest to northeast with northerly dips of 30° to 50°. Cleavage trends north to northeast, with 50° to 80° northwest dips, except where folding is present.

PRECIOUS METAL MINERALIZATION

The mineralization is typically epithermal with veins and vein breccias enveloped by silicified and bleached clay alteration zones in the wallrock. Silicification of the brecciated wall rock adjacent to the vein contact and of fragments within the vein breccias is distinguished by very fine vugs in the rock, yellow weathering colour and drusy quartz lining cavities in the breccia. The vein and silicified zone is commonly 1 to 3 m wide. Enveloping the vein zone, disseminated pyrite content increases away from the veins with decreasing silicification in the phyllic alteration zone that can extend up to 10 m in width. Argillic alteration is distinguished by the presence of kaolinite and montmorillinite which generally developed throughout the feldspar porphry outside of the silicic and phyllic zones. The mineralized and altered feldspar porphyry dyke ranges from 8 to 33 m wide.

The gold- and silver-rich sulphide consists of pyrite, arsenopyrite, sphalerite, galena, sulfosalts, bornite, stibnite and chalcopyrite. Gold is genetically related to an early pyrite phase of the mineralization and occurs as 5 to 40 micron-sized inclusions in the pyrite (Lister, 1988). The gold grains have a fineness of approximately 800 (Saager and Bianconi, 1971; Lister, 1988). The gold grains have been exposed by oxidation of the sulphide minerals as well as by post-mineral cataclasis.

Assay results indicate that the breccia-hosted mineralization has higher gold grades relative to the silver values than the vein-hosted mineralization. The gold to silver ratio from assays of the breccia-hosted mineralization is approximately 1:3, whereas that of the vein mineralization is approximately 1:7. The silver content appears to be related to the amount of the base metal in the ore. Galena and sphalerite are more abundant in the vein mineralization than in the breccia-type mineralization.

SUMMARY

Gold-silver veins and breccias at Mount Nansen are epithermal deposits related to a variety of structural settings including intrusive contacts, narrow fractures or breccia bodies. The Brown-McDade mine has exploited two types of deposits: a vein system hosted by a massive feldspar porphyry dyke that has intruded along an igneous-metamorphic contact zone, and a pipe-like breccia body within competent metamorphic rocks. A swarm of northwest-trending veins occupy fractures within metamorphic rocks 2 km west of the Brown-McDade in the Huestis-Flex-Webber system. Other mineralized breccia bodies have been explored within the Mount Nansen porphyry complex and in the foliated plutonic rocks north of the Brown-McDade deposit.

The mineralization is likely genetically related to the Mount Nansen Porphyry complex located in the centre of the Mount Nansen property. Gold has been mined from placer deposits flanking the porphyry system, and low-grade precious metal values occur within silicified breccia zones within the copper-molybdenum porphyry system.

Information derived from detailed mapping and sampling has lead to a revised geological model for the precious metal deposits in the vicinity of the Mount Nansen porphyry complex. The origional exploration model focussed on northwest-trending fault-controlled veins related to large scale regional structures. Numerous gold-silver occurrences and anomalies on the property will be re-evaluated and investigated applying the evolving geological model and concepts (Fig. 2).

In profile, the Brown-McDade deposit exhibits a well developed near-surface oxide gold enrichment zone for both the vein- and breccia-type bodies. Priority exploration targets are the potentially enriched oxidized zones capping breccia pipes or veins within large feldspar porphyry intrusions. Numerous gold-in-soil anomalies have been untested in the competent homogeneous rocks north of the Brown-McDade deposit. More anomalies occur closer to the Mount Nansen porphyry complex.

The narrow vein systems hosted by the metamorphic rocks are potentially economic because of the high gold-silver values if the density of veining can produce signifigant volumes for bulk mining. Skarn-type alteration has been noted at several localities in limy rock units along road cuts between the Brown-McDade deposit and the Huestis-Flex-Webber vein system. No gold values have been obtained from these occurrences, but this potential type of mineralization was not previously recognized or evaluated in the Mount Nansen camp.

ACKNOWLEDGEMENTS

The author is indebted to his co-workers who have contributed to the successful operation of the Brown-McDade mine, especially geologists Neil Firt and Ken Lord. I would also like to thank BYG Natural Resources Inc. for support in the preparaton of this report. Diane Emond edited this report and Panya Lipovsky drafted relevant figures.

REFERENCES

Anderson, F. and Stroshein, R., 1997. Geology of the Flex gold-silver vein system, Mount Nansen area, Yukon. *In:* Yukon Exploration and Geology 1997, Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 139-143.

Carlson, G.G., 1987. Geology of Mount Nansen (115-I/3) and Stoddart Creek (115-I/6) map areas, Dawson Range, central Yukon. Exploration and Geological Services Divison, Yukon, Indian and Northern Affairs Canada, Open File 1987-2.

Johnston, Stephen, T. and Mortensen, James, K., 1994. Regional setting of porphyry Cu-Mo deposits, volcanogenic massive-sulphide deposits, and mesothermal gold deposits in the Yukon-Tanana Terrane, Yukon. *In:* Yukon Metallogeny: Recent Developments, Abstracts and Proceedings, Canadian Institute of Mining and Metallurgy, District 6 Annual General Meeting, J.L. Jambor (ed.), p. 30-34.

Lister, D., 1988. Report on the sulphide mineralogy of the Brown-McDade zone, Mount Nansen property. Unpublished company report, BYG Natural Resources Inc. and Chevron Minerals Ltd., 49 p.

Saager, R. and Bianconi, F., 1971. The Mount Nansen gold-silver deposit, Yukon Territory, Canada. Mineralium Deposita (Berl.), vol. 6, p. 209-224.

Sawyer, J.P.B. and Dickinson, R.A., 1976. Mount Nansen, porphyry copper and copper-molybdenum deposits of the calc-alkaline suite. *In:* Porphyry Deposits of the Canadian Cordillera, T. G. Schroeter (ed.), Canadian Institute of Mining and Metallurgy, Special Vol. 15, p. 336-343.

The Wolf property — 1998 update: Volcanogenic massive sulphides hosted by rift-related, alkaline, felsic volcanic rocks, Pelly Mountains, Yukon

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Gibson, A.M., Holbek, P.M. and Wilson, R.G., 1999. The Wolf property – 1998 update: Volcanogenic massive sulphides hosted by rift-related, alkaline, felsic volcanic rocks, Pelly Mountains, Yukon. *In:* Yukon Exploration and Geology 1998, C.F. Roots and D.S. Emond (eds.), Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 237-242.

ABSTRACT

The Wolf property is situated within the Pelly Mountains, 90 km south of Ross River, Yukon. The Mississippian felsic volcanic and sedimentary rocks which underlie the Wolf property are part of a belt that occurs within the Pelly-Cassiar platform, a miogeoclinal sequence thought to be part of ancestral North America. Much of the bedrock exposure in the region is along the northeastern edges of southwesterly dipping, imbricate thrust sheets. The felsic volcano-sedimentary sequence on the Wolf property is approximately 900 m thick and bounded by two thrust panels of lower Paleozoic platformal carbonate sequences. Volcanic stratigraphy is characterized by high potassium geochemistry, a variety of pyroclastic grain sizes, and high-energy fragmental and low-viscosity flow textures. The chemistry of the volcanic rocks and their tectono-stratigraphic setting indicates deposition within an intra-continental rift.

Volcanogenic sulphide mineralization and exhalative barite occur at four stratigraphic levels within the Wolf property. The Wolf deposit is hosted within a laterally extensive sheet of massive sulphide mineralization at the upper stratigraphic level and has been defined by 30 diamond-drill holes over a 600 m strike length and a 500 m width (down-dip). Thickness of zinc, lead and silver bearing massive sulphide ranges from 2 to 25 m. A bulk of the deposit is contained within a higher grade "keel" that has a strike length of 125 m, a down-dip length of 400 m, an average thickness of 12 m and dips 45 degrees to the south. The deposit has an inferred resource of 4.1 million tonnes grading 6.2% Zn, 1.8% Pb and 84 g/t Ag, and is open along strike and down-dip. Exploration potential of the property has been enhanced by the discovery of the East Slope zone, 1200 m east of the Wolf deposit. Chemical zoning within the mineralization and peripheral alteration, and deposit morphology indicate that stratigraphy may be overturned.

RÉSUMÉ

La propriété Wolf se trouve dans la chaîne St. Cyr des monts Pelly, à environ 90 km au sud de Ross River (Yukon). La propriété repose sur des roches volcaniques felsiques et des roches sédimentaires dévono-mississippiennes. Il y a minéralisation sulfurée et/ou minéralisation en barite massive à bien laminée à quatre niveaux stratigraphiques distincts dans un amoncellement, d'une épaisseur d'environ 900 m, de roches volcaniques trachytiques à teneur élevée en K intercalées de sédiments argileux. Bien que les études de cartographie régionale n'aient pas précédemment permis la documentation à grande échelle des plis couchés de la région, un certain nombre de caractéristiques observées dans des carottes de forages indiquent que la séquence minéralisée pourrait être renversée. Des failles chevauchantes d'orientation nord-est séparant des séquences carbonatées paléozoïques de plate-forme étendues limitent la séquence de roches volcaniques felsiques encaissantes.

Dans la propriété Wolf, la minéralisation s'est formée dans des corps tabulaires de sulfures massifs latéralement étendus renfermant couramment des quantités moindres de dolomie ferrifère et plus rarement de la barite. L'horizon sulfuré supérieur du gisement Wolf a été recoupé par trente et un trous de sonde sur une longueur de 600 mètres dans la direction de la couche et sur jusqu'à 500 mètres vers l'aval-pendage; il présente une épaisseur variant de 2 mètres à plus de 25 mètres. Une «quille» à teneur plus élevée et d'une plus grande épaisseur a été définie sur une largeur approximative de 120 m et elle présente une épaisseur moyenne de 12 m sur plus de 400 m en aval-pendage. Une faille normale fortement inclinée avec rejet vertical de 65 m divise en deux parties égales la quille de l'horizon supérieur. Parmi les textures observées des sulfures, mentionnons : de la pyrite massive à grains fins avec sulfures de métaux communs disséminés, de la sphalérite, de la galène et de la roche carbonatée laminées ainsi que de la sphalérite et de la galène botryoïdes dans une gangue de roche carbonatée de couleur chamois avec Fe-Mg. La chalcopyrite brille par son absence générale dans l'horizon supérieur, bien qu'elle ait été observée dans des petits filons carbonatés de quartz et dans des bandes proximales sous-jacentes aux sulfures massifs.

Une nouvelle découverte, la zone East Slope, a été faite pendant la campagne de travaux sur le terrain de 1998. Situés à 1,2 km au sud-est du gisement Wolf dans la direction de la couche, les sulfures rubanés semi-massifs à massifs se présentent du point de vue stratigraphique approximativement à 70 m sous la position de l'horizon du gisement Wolf. Des sulfures massifs ont été recoupés par quatre trous de sonde et des teneurs atteignant jusqu'à 5,7 % en Zn, 2,1 % en Pb et 43,6 g/t d'argent on été relevées sur une épaisseur réelle de 4,6 m.

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INTRODUCTION

The Wolf property is located approximately 90 km southeast of Ross River, Yukon in the Pelly Mountains (Fig. 1). The property lies within NTS map sheets 105G/5 and 6, with the centre of the property at latitude 62°20'N and longitude 131°20'W. The property is best accessed by helicopter.

Owned by YGC Resources Ltd., the property was optioned by Atna Resources Ltd. in 1995 under an agreement which allows for Atna to earn a 65% interest in the claims for expenditures of $1.5 million over a five-year period. Atna has completed its option requirements and the project is now in the joint venture phase. The property presently comprises 23 mineral claims covering an area of approximately 481 hectares.

HISTORY

The Wolf property has been explored intermittently for the last 40 years. From the first recorded discovery of mineralization in 1955, the property has been the subject of numerous exploration programs: Newmont Mining Corp. staked the property and conducted geochemical sampling in 1966; Hesca Resources Ltd. restaked in 1972 and drilled two "x-ray" holes totaling 61 m in 1974; Newmont restaked in 1976 and conducted geochemical sampling, EM and magnetometer surveys, and 528 m of drilling in 1978; Amax of Canada Ltd. conducted a program of additional mapping and soil sampling (Harris, 1982); and Cominco Ltd. carried out more detailed gridding, soil sampling, mapping, and a UTEM ground geophysical survey between 1990 and 1993 (MacRobbie, 1992; Holroyd, 1993). Atna Resources Ltd. optioned the property in 1995 and conducted reconnaissance evaluation (Kallock, 1995), and a program of soil sampling, hand trenching and diamond drilling in 1996 (Schmidt, 1997). The three holes, in 1996, intersected significant, but sub-economic zinc, lead and silver. More drilling by Atna followed, and WF97-07, the fourth hole of the 1997 program, intersected 25.2 m of 6.9% zinc, 2.8% lead, and 139 g/t silver. Eight additional holes were drilled, all of which intersected the upper horizon of massive sulphides of varying thickness and grade (Holbek and Wilson, 1997).

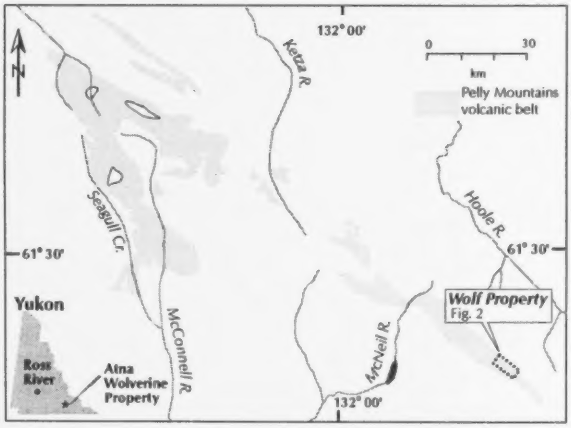


***Figure 1.** Location of Wolf property in the Pelly Mountains volcanic belt.*

GEOLOGY

REGIONAL SETTING

The volcano-sedimentary rocks hosting the Wolf deposit form a narrow arcuate belt that extends 80 km along a northwesterly trend (Fig. 1). The volcanic rocks of this belt are characterized by high potassium content and, locally, bedded barite and volcanogenic massive sulphide deposits and showings. The Pelly Mountain Volcanic Belt is early to middle Paleozoic in age and occurs within the Pelly-Cassiar Platform, considered to be part of ancestral North America (Tempelman-Kluit, 1977).

Structure in the region is dominated by the Tintina Fault system and associated trench which is located 12 km east of the Wolf property and runs approximately parallel to the structural grain of the region. Post-late Triassic deformation produced a series of southwest-dipping thrust panels and northeasterly verging folds within the region (Gordey, 1977). Late normal faults crosscut earlier structures and divide the region into numerous fault-bounded blocks that commonly represent different structural levels. Metamorphism and degree of deformation varies from block to block but generally increases in a westerly direction. Metamorphism varies from lower to upper greenschist facies.

The regional tectono-stratigraphic setting, the high potassium geochemistry of the volcanic rocks, and the presence of bedded barite and volcanogenic massive sulphide deposits, indicate that the Pelly Mountain volcanic belt was likely deposited in a continental rift-type environment (Mortensen and Godwin, 1982).

PROPERTY GEOLOGY

The Wolf deposit occurs within an approximately 900 metre thick sequence of trachyte flows, lapilli and crystal tuffs, and lesser intercalated epivolcaniclastic and sedimentary rocks. This sequence of felsic volcanic rocks is bounded by northeasterly directed thrust faults, separating two extensive platformal carbonate sequences interpreted to be of lower Paleozoic age. Thrusts trend northwest and dip moderately towards the southwest. The felsic package strikes northwesterly and dips moderately to steeply (average 45°) to the southwest (Fig. 2).

Surface mapping at Wolf is hampered by weathering of pyritic, Fe-carbonate-altered rocks. Individual lithologies are difficult to identify, as colour and texture are often governed more by degree of alteration and weathering than parent lithology. In any volcanic pile, individual lithologies tend to be highly variable with respect to thickness and areal distribution, due to irregular paleodepositional surfaces, proximity to volcanic vents, and dynamic to catastrophic local tectonics. Consequently, correlation of individual rock types between widely spaced drill holes and outcrops is difficult. Rock types, therefore, must be grouped into correlatable units, usually representing distinct igneous and/or sedimentary depositional environments. These units, as grouped at the Wolf property, are described below. The present geological plan (Fig. 2) is a simplification of field mapping based on stratigraphic groupings determined from drill core.

STRATIGRAPHY

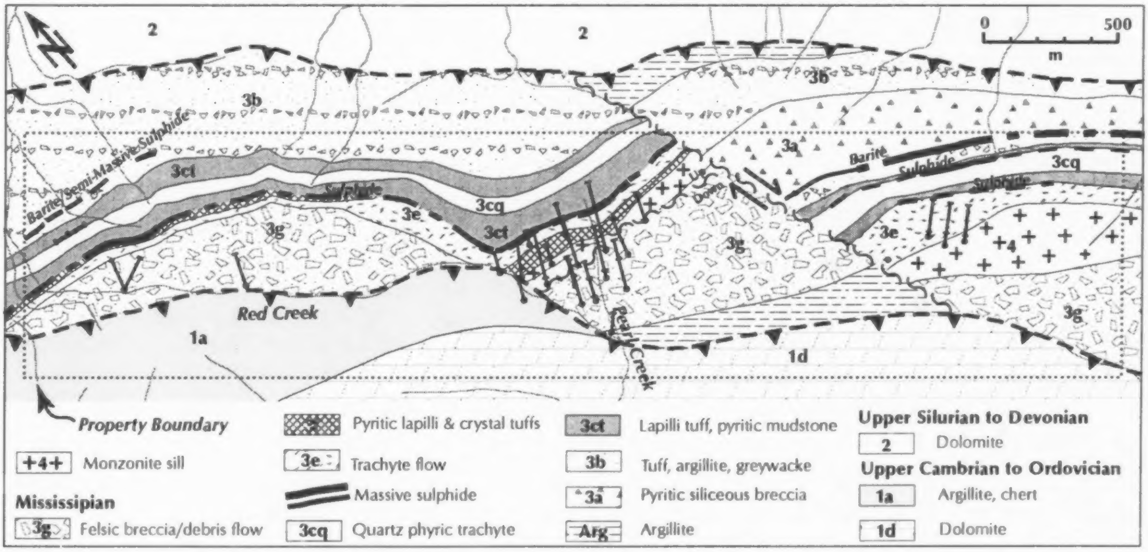
The oldest rocks on the property are Upper Cambrian to Ordovician platformal carbonate rocks which occur in the uppermost thrust sheet (Unit 1) and consist of limestone to dolomite with interbedded shales and tan to reddish weathering dolostone (Figs. 2 and 3). The next oldest unit is interpreted to be the Upper Silurian to Devonian carbonates in the lower thrust plate on the northeastern edge of the property (Unit 2). The mineralized Upper Devonian to Mississippian volcanic package is bounded by these two carbonate thrust plates, and has been subdivided into eight units (3a-g and 4; Fig. 2).

The volcanic sequence hosting mineralization (Unit 3) was previously thought to be right side-up on the basis that Unit 3g, consisting of polymictic debris flows, lahars, and volcanic conglomerates composed of fragments from almost all of the volcanic sequence, with minor interbedded greywacke and argillite, occurred at the top of the sequence. However, in the Wolf deposit and East Slope areas, a monzonite sill (Unit 4) underlies Unit 3g below a faulted contact. If this sill was emplaced along a thrust fault then Unit 3g may not be in its correct stratigraphic position and cannot be used for a "tops" determination. The following descriptions are therefore based on structural, rather than stratigraphic positions.

The lowermost unit (3b) in the volcanic sequence is a poorly defined assemblage of ash tuffs, greywackes, argillite and locally, lapilli tuffs. The lapilli tuffs of this unit are characterized by relatively coarse, elliptical fragments (20 - 40 mm) that are altered to a soft greenish yellow. The matrix appears to be serpentinized or chloritized but chemically, Mg values are low. Further subdivision of this unit may be possible with additional drill data. Unit 3a is a highly pyritic, siliceous (?) felsic breccia/flow that overlies 3b in the East Slope area but not at the Wolf deposit. Texturally, this unit appears to be vent proximal and may even be part of a flow-dome complex. Directly above Unit 3a is a laminated barite-carbonate-sulphide exhalative unit up to 18 m in thickness. This exhalite likely correlates with the lowermost barite horizon below the Wolf deposit (those exposed in the Newmont trenches) and the massive galena showing at the base of the cliffs on the northwest side of Mt. Vermilion.

Unit 3c hosts the East Slope zone and the middle sulphide horizon in the Wolf deposit area. The unit consists of ash tuffs, epivolcaniclastic rocks, trachyte flows and/or sills, pyritic mudstones and exhalative material, including massive sulphide horizons. The unit is distinct in that the tuffaceous and flow and/or sill rocks commonly contain fine quartz grains. The trachyte flows and/or sills and adjacent tuffaceous units typically display unusual textures formed by fine to coarse disseminated to aggregated elliptical Fe-dolomite nodules. It has been speculated that these textures are a form of pepperite caused by the injection of magma into wet unconsolidated tuffs and volcanic sediments. The percentage of quartz grains in these rocks appears to decrease from southeast to northwest.

Unit 3d hosts the Wolf deposit and consists of altered lapilli and ash tuffs, pyritic ash tuff, mudstone, laminated barite and massive to semi-massive sulphide mineralization. The tuffaceous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Sulphide
Up
Down
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4
3g
Red Creek
1a
Pearl Creek
1d
Property Boundary
+4+ Monzonite sill
Mississipian
3g Felsic breccia/debris flow
Pyritic lapilli & crystal tuffs
3e Trachyte flow
Massive sulphide
3cq Quartz phyric trachyte
3ct Lapilli tuff, pyritic mudstone
3b Tuff, argillite, greywacke
3a Pyritic siliceous breccia
Arg Argillite
Upper Silurian to Devonian
2 Dolomite
Upper Cambrian to Ordovician
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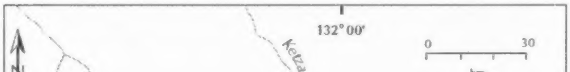

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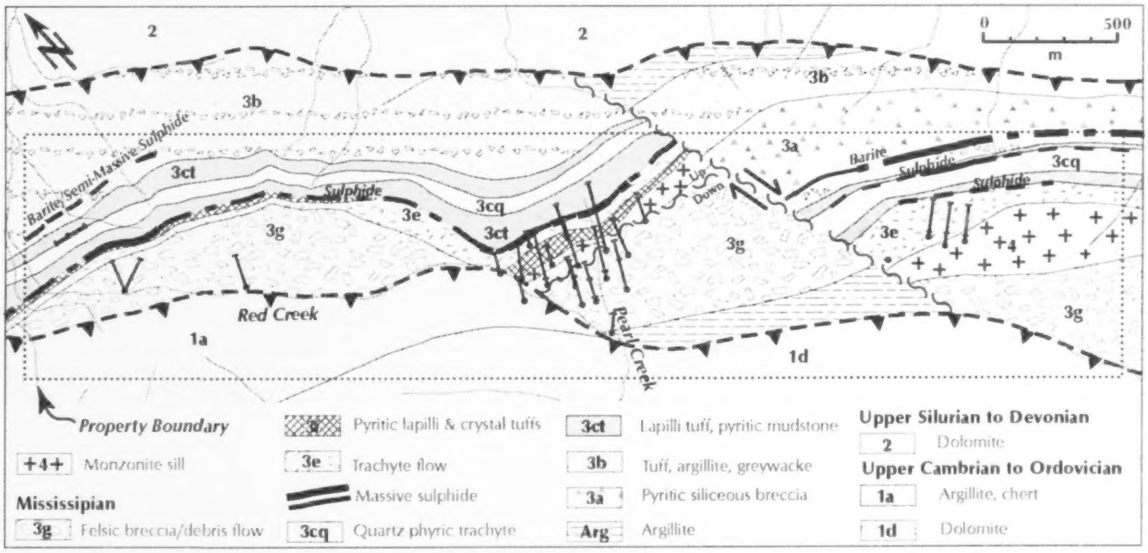

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3b
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3a
Barite/Semi-Massive Sulphide
3ct
Sulphide
3e
3cq
3ct
3g
Up
Down
Barite
Sulphide
Sulphide
3cq
3e
4
3g
3g
Red Creek
Pearl Creek
1a
1d
Property Boundary
+4+ Monzonite sill
Mississipian
3g Felsic breccia/debris flow
3f Pyritic lapilli & crystal tuffs
3e Trachyte flow
Massive sulphide
3cq Quartz phyric trachyte
3ct Lapilli tuff, pyritic mudstone
3b Tuff, argillite, greywacke
3a Pyritic siliceous breccia
Arg Argillite
Upper Silurian to Devonian
2 Dolomite
Upper Cambrian to Ordovician
1a Argillite, chert
1d Dolomite

Figure 2. Geological plan of the Wolf property.

rocks of this unit are similar to those of 3f and are only different units due to separation by the trachyte flows of unit 3e. The pyritic-lapilli tuff unit overlies the mineralization and is laterally extensive. This lithology is laterally extensive and conspicuous due to strong sericite alteration and the presence of 10 to 20%, 3 to 15 mm fragments of massive pyrite and rarely, other sulphide minerals. There is no discernible zonation with respect to size and abundance of the sulphide fragments at the property scale, suggesting that the sulphide fragments originated in vent proximal mineralization caught in a phreatomagmatic explosion.

The trachyte flows of Unit 3e are the most continuous lithology in the sequence. They are present almost everywhere in the belt and are easily recognizable due to the propensity to form both cliffs and, with 5 to 20% finely disseminated pyrite, gossans. These units may be partly intrusive but most of the textures seen in drill core, including amygdules, flow-top breccias, and rare pillows, support a flow origin. Although felsic in composition, the high potassium content lowers the viscosity of the magma to the point where features more commonly associated with flood basalts occur in this unit. In the vicinity of the Wolf deposit the thickness of trachyte is variable and appears to be in an inverse relationship to the thickness of the sulphide mineralization (thin trachyte over thick sulphides and vice-versa). Commonly, but not always, the massive sulphide mineralization is separated from the trachyte flows by pyrite-lapilli tuff and/or a thin layer of argillite.

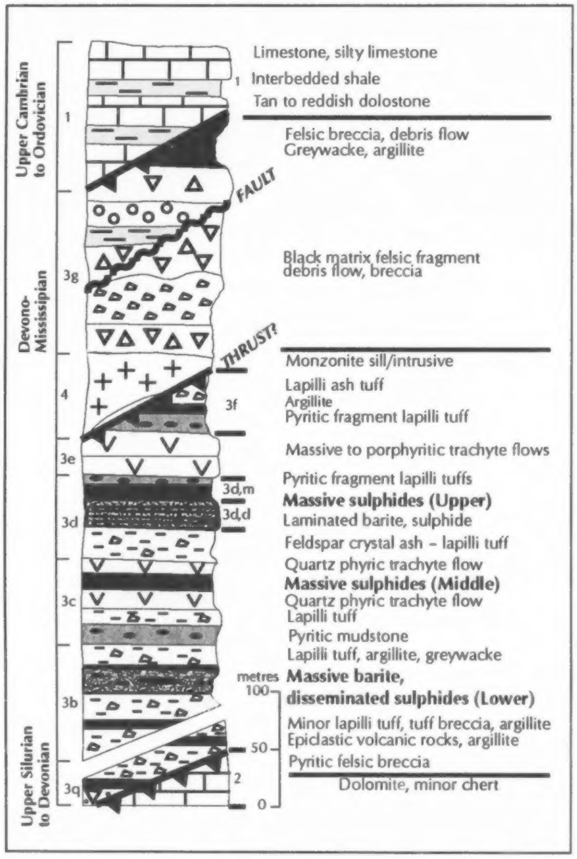

Upper Cambrian to Ordovician
Devono-Mississipian
Upper Silurian to Devonian
1
3g
4
3e
3d
3c
3b
3q
2
3f
3d,m
3d,d
FAULT
THRUST?
Limestone, silty limestone
Interbedded shale
Tan to reddish dolostone
Felsic breccia, debris flow
Greywacke, argillite
Black matrix felsic fragment debris flow, breccia
Monzonite sill/intrusive
Lapilli ash tuff
Argillite
Pyritic fragment lapilli tuff
Massive to porphyritic trachyte flows
Pyritic fragment lapilli tuffs
Massive sulphides (Upper)
Laminated barite, sulphide
Feldspar crystal ash - lapilli tuff
Quartz phyric trachyte flow
Massive sulphides (Middle)
Quartz phyric trachyte flow
Lapilli tuff
Pyritic mudstone
Lapilli tuff, argillite, greywacke
Massive barite, disseminated sulphides (Lower)
Minor lapilli tuff, tuff breccia, argillite
Epiclastic volcanic rocks, argillite
Pyritic felsic breccia
Dolomite, minor chert
metres
100
50
0

Figure 3. Schematic stratigraphy of Wolf deposit.

Unit 3g, as described above, consists of lahars and/or debris flows and volcanic conglomerates interbedded with minor greywacke and argillite. The fragments are dominantly trachytic but other volcanic and sedimentary lithologies also occur. The matrix commonly consists of fine-grained black chlorite (hence the field term: black matrix breccia) although, locally, the matrix can be bleached. Disseminated pyrite occurs locally, both within the trachytic fragments and also in the matrix, and rare patches of orange sphalerite are also observed. The presence of sulphides, particularly sphalerite, in the matrix of this unit is enigmatic. Drilling has encountered up to 190 m true thickness of this unit.

Fine- to coarse-grained, equigranular to weakly porphyritic monzonite forms Unit 4. Chemically, this unit is distinct from the other igneous lithologies in that the potassium and sodium contents are approximately equal (in most other rocks on the property, the ratio is 8 or 9:1). In drill core, this unit commonly appears altered and locally, intensely chloritized, however, the outcrops on the southern end of the property, mapped as syenite by Gordey (1977) and others, appear to be relatively fresh.

STRUCTURE

The structure of Wolf property is predominately influenced by the thrust panels which bound the volcanic succession, and dip moderately to the southeast. The lower thrust fault has previously been described as an unconformity (Gordey, 1977; Hunt, 1997), however, the thrust interpretation is retained herein for the following reasons: first, although the actual volcanic-carbonate contact is rarely exposed, the volcanic rocks near the contact commonly display evidence of tectonic disruption including folding of foliation; second, the contact cuts across the volcanic stratigraphy at a shallow angle.

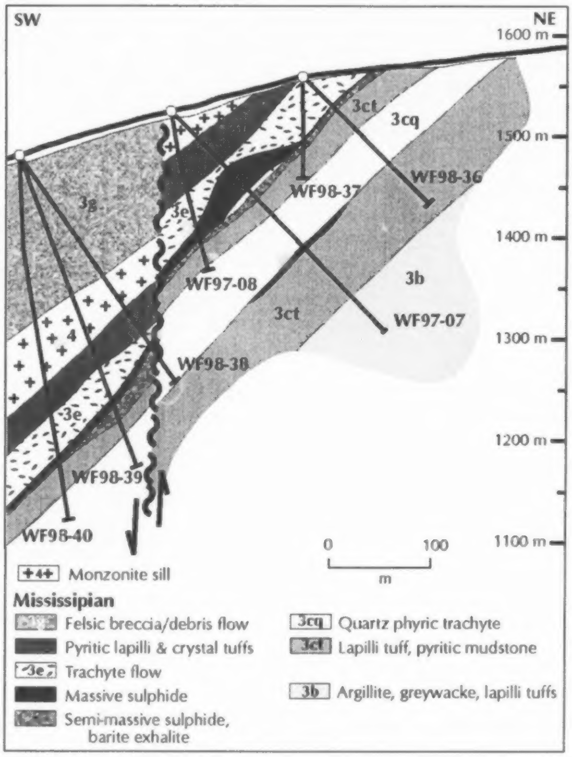
A weak to strong, bedding parallel, foliation is developed in most volcanic and sedimentary units. Diversion of bedding and foliation planes, indicative of folding, has only been observed on the northern end of the property. Small-scale minor folds are common in drill core but megascopic folds in outcrop are rare. However, regional scale nappe structures are observed in the Pelly Mountain Volcanic Belt at the MM property (Mortensen, 1979) and in other rocks of the Pelly Cassiar Platform, immediately south of the Ketza River, and are consistent with the regional tectonic history. The homoclinal stratigraphic sequence of the Wolf property is likely part of a limb of a large fold. Additional limbs may be present north of the Wolf property where the width of the volcanic belt increases substantially.

Late stage faulting is evident on the property in a number of locations. The most prominent is a north-trending, steeply dipping fault that displaces stratigraphy for 700 m in a right lateral direction (Fig. 2). A less prominent, but economically significant, fault is the easterly trending fault that down-drops the southern part of the Wolf deposit (Fig. 4).

MINERALIZATION

The Wolf deposit was discovered in 1997 by the fourth drill hole of a planned four-hole program. The discovery hole, WF97-07, intersected a true thickness of 25.2 m grading 6.9% zinc, 2.8% lead and 138.6 g/t silver (Fig. 4). Mineralization occurs as stratiform pyrite, carbonate, sphalerite, galena and barite, with rare specular hematite and chalcopyrite.

Although conclusive evidence is lacking, it appears the stratigraphy at Wolf may be an overturned limb of a recumbent fold. The mineralogical sequence appears inverted so that stringer mineralization occurs above the massive sulphide deposit and an extensive barite-carbonate exhalite occurs below it. Argillite and other sediments increasingly dominate the stratigraphy over volcanic rock below the lowermost mineralized horizon. If the stratigraphy were inverted these sediments could represent a period of quiescence and sedimentary deposition after a period of active volcanism. Intensity of alteration does not appear to be a conclusive guide because highly altered rocks have been intersected above and below the mineralized horizons. However, the concentration of disseminated to massive pyrite, quartz stringers, and carbonate alteration does appear more prevalent in the trachytic flows directly above the Wolf deposit than in rocks below.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+4+ Monzonite sill
Mississipian
Felsic breccia/debris flow
Pyritic lapilli & crystal tuffs
3e Trachyte flow
Massive sulphide
Semi-massive sulphide, barite exhalite
3cq Quartz phyric trachyte
3ct Lapilli tuff, pyritic mudstone
3b Argillite, greywacke, lapilli tuffs

Figure 4. *Geological cross section of Wolf deposit.*

A total of 31 holes have intersected and defined the Wolf deposit which occurs as a tabular massive sulphide horizon across a 600 metre strike length, and approximately 500 m in the down-dip direction. A higher grade, thicker "keel" to this horizon, which is open at depth, was defined over a 120 m width, 12 m average thickness, and 400 m down-dip extent. A thrust fault is interpreted to have terminated the mineralization towards the northwest. The Wolf deposit is still open to expansion along strike to the east and down-dip. The massive sulphide mineralization consists primarily of fine-grained pyrite with bands of amber-coloured sphalerite and fine-grained, steely-grey galena. Also present is medium-grained botryoidal sphalerite and galena within a gangue of buff-coloured Fe-Mg carbonate and more rarely barite. Generally, sulphide intersections within the upper horizon grade from banded galena/pyrite to variably textured medium-grained sphalerite-pyrite. An extensive semi-massive barite/carbonate exhalite occurs immediately below the massive sulphide (Fig. 4). The barite/carbonate hosts disseminated to semi-massive sulphides in a banded, well-foliated fine-grained matrix which generally maintains a relatively uniform thickness of three to five metres throughout the Wolf deposit area. The baritic exhalite occurring on the bottom of the massive sulphide, and the upward doomed shape caused by increase in thickness of the mineralization, as indicated by the upper part of the hole WF98-07, are consistent with the interpretation of an overturned sequence.

The massive sulphide intervals are geochemically anomalous in copper (100-600 ppm), with individual assays up to 0.1%. Copper values in the massive sulphides do not appear to vary significantly between horizons or zones. Although generally absent, chalcopyrite has been observed occurring within mineralized quartz-carbonate stringers in two drill holes below the upper horizon (Wolf deposit). In drill hole WF98-24, the stringers formed a zone 7.1 m thick averaging 0.1% Cu within a trachyte flow. A narrow, high grade massive sulphide horizon directly below the stringer zone assayed 1.4% Cu, 9.8% Zn, 1.1% Pb and 11.3 g/t Ag over 0.5 m. The association of chalcopyrite rich stringers above this copper-enriched massive sulphide horizon is suggestive of an overturned sequence of stringer (feeder?) zone stratigraphically "below" a sulphide horizon.

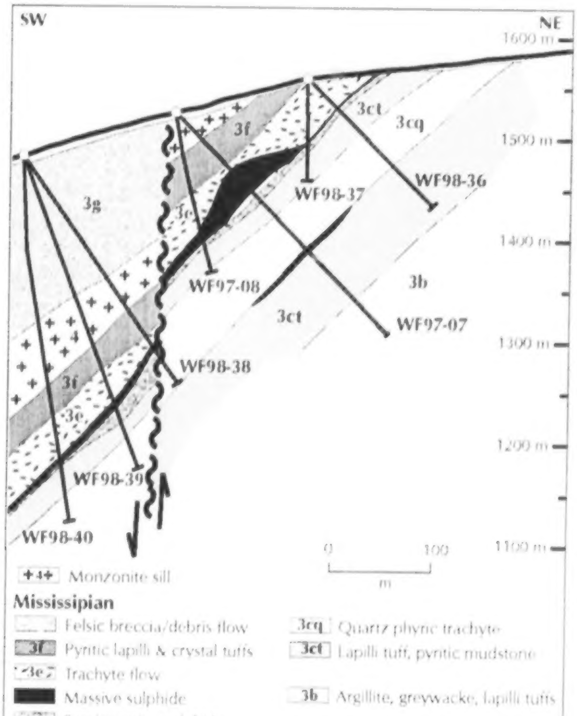
EAST SLOPE ZONE

A total of six holes were successfully completed on the East Slope target in 1998 encompassing 1292 m of diamond drilling. After two failed previous attempts, the first hole completed on the East Slope target, WF98-33, intersected a 3.9 m true width of massive and semi-massive sulphides grading 4.6% Zn, 2.1% Pb and 30.0 g/t Ag. An approximately 80 m thick sequence of disseminated lead-zinc mineralization was intersected in the lateral direction (Fig. 2). A less prominent, but economically significant, fault is the easterly trending fault that down-drops the southern part of the Wolf deposit (Fig. 4).

MINERALIZATION

The Wolf deposit was discovered in 1997 by the fourth drill hole of a planned four-hole program. The discovery hole, WF97-07, intersected a true thickness of 25.2 m grading 6.9% zinc, 2.8% lead and 138.6 g/t silver (Fig. 4). Mineralization occurs as stratiform pyrite, carbonate, sphalerite, galena and barite, with rare specular hematite and chalcopyrite.

Although conclusive evidence is lacking, it appears the stratigraphy at Wolf may be an overturned limb of a recumbent fold. The mineralogical sequence appears inverted so that stringer mineralization occurs above the massive sulphide deposit and an extensive barite-carbonate exhalite occurs below it. Argillite and other sediments increasingly dominate the stratigraphy over volcanic rock below the lowermost mineralized horizon. If the stratigraphy were inverted these sediments could represent a period of quiescence and sedimentary deposition after a period of active volcanism. Intensity of alteration does not appear to be a conclusive guide because highly altered rocks have been intersected above and below the mineralized horizons. However, the concentration of disseminated to massive pyrite, quartz stringers, and carbonate alteration does appear more prevalent in the trachytic flows directly above the Wolf deposit than in rocks below.


SW
NE
1600 m
1500 m
1400 m
1300 m
1200 m
1100 m
3f
3ct
3cq
3g
3e
WF98-37
WF98-36
WF97-08
3b
3ct
WF97-07
WF98-38
3f
3e
WF98-39
WF98-40
0
100
m
+++ Monzonite sill
Mississipian
Felsic breccia/debris flow
3f Pyritic lapilli & crystal tuffs
3e Trachyte flow
Massive sulphide
Semi-massive sulphide, barite exhalite
3cq Quartz phyric trachyte
3ct Lapilli tuff, pyritic mudstone
3b Argillite, greywacke, lapilli tuffs

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CONCLUSIONS

The 1998 exploration program followed up the 1997 discovery and located the down dip extension to the keel of the mineralized upper horizon. Through diamond drilling, the geology of the property has become much better understood, previous surface mapping having been hampered by supergene alteration related to pyrite and Fe-carbonate rich rocks.

The primarily trachytic felsic volcanic package hosts at least four separate horizons of volcanogenic massive sulphide mineralization. Mineralization seems to be laterally extensive as the East Slope area was drill-tested and found to contain massive sulphide mineralization; the thickest horizon located at a stratigraphic level approximately 70 m below the Wolf deposit. Potential is high to expand known deposits and zones of mineralization, and to locate new deposits.

Faulting has proven to be a significant factor in locating massive sulphide horizons at the Wolf property. A normal fault with unknown, but limited, strike-slip movement has down-dropped the south side of the Wolf deposit by 65m.

It is postulated that the volcanic sequence hosting the Wolf deposit may be overturned. Although little evidence exists from regional mapping to support the presence of a recumbent fold, observations from drill core which support an inverted VMS mineralized environment include: mineralized stringer zones above massive sulphide horizons; an irregular upper contact and a relatively "flat" lower contact of the massive sulphides; an extensive barite-carbonate horizon spatially below the Wolf deposit massive sulphides; and pyrite rich and highly carbonate-altered trachyte flows spatially above the upper horizon.

REFERENCES

Gordey, Steven P., 1977. Stratigraphy, structure, and tectonic evolution of the southern Pelly Mountains in the Indigo lake area, Yukon Territory. Unpublished Ph.D. thesis, Queen's University, Kingston, Ontario.

Harris, F.R., 1982. Geological, geochemical assessment report, Hoole River Property, Zap 1-6, Zoo 1-28, Assessment report for Amax of Canada Limited, Mineral Resources Directorate, Yukon, Indian and Northern Affairs Canada.

Holbek, P.M. and Wilson, R.G., 1997. The Wolf discovery: a Kuroko style volcanogenic massive sulphide deposit hosted by rift-related, alkaline, felsic volcanic rocks. *In:* Yukon Exploration and Geology 1997, Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 115-120.

Holroyd, R.W., 1993. Report on geophysical surveys, Wolf property, Watson Lake mining district, Yukon. Assessment report for Cominco Ltd., Mineral Resources Directorate, Yukon, Indian and Northern Affairs Canada.

Hunt, J.A., 1997. Massive sulphide deposits in the Yukon-Tanana and adjacent terranes. *In:* Yukon Exploration and Geology 1996, Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 35-45.

Kallock, Paul, 1995. Geology rock and soil seochemical survey, Wolf 1-18 mineral claims, Watson Lake mining district, Mt. Vermilion Area, Yukon Territory. Assessment report prepared for Atna Resources Ltd., Mineral Resources Directorate, Yukon, Indian and Northern Affairs Canada.

Mortensen, J.K., 1979. Stratigraphic, structural, and tectonic setting of an Upper Devonian-Mississippian volcanic-sedimentary sequence and associated base metal deposits in the Pelly Mountains, southeastern Yukon Territory. Unpublished M.Sc. thesis, University of British Columbia, Vancouver, B.C.

Mortensen, J.K. and Godwin, C.I., 1982. Volcanogenic massive sulphide deposits associated with high alkaline rift volcanics in the southeastern Yukon Territory. Economic Geology, vol. 77, p. 1225-1230.

MacRobbie, Paul A., 1992. Year-end report, Fox-Wolf-Lynx property, soil geochemistry and geological mapping, Watson Lake mining district, Yukon. Assessment report for Cominco Ltd., Mineral Resources Directorate, Yukon, Indian and Northern Affairs Canada.

Schmidt, Uwe, 1997. Report on geology, grid soil geochemical survey and diamond drilling of the Wolf property, Watson Lake mining district. Assessment report for Atna Resources Ltd., Mineral Resources Directorate, Yukon, Indian and Northern Affairs Canada.

Tempelman-Kluit, D.J., 1977. Quiet Lake (105F) and Finlayson lake (105 G) map areas. GSC Open File 486, Scale 1:250 000.

The Scheelite Dome gold project, central Yukon

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Hulstein, R., Zuran, R., Carlson, G.G. and Fields, M., 1999. The Scheelite Dome gold project, central Yukon. *In:* Yukon Exploration and Geology 1998, C.F. Roots and D.S. Emond (eds.), Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 243-248.

ABSTRACT

La Teko Resources Ltd. acquired the Scheelite Dome gold property from Kennecott Canada Exploration Inc. in 1998. Kennecott had explored the central Yukon property since 1994. The strongly deformed Yusezyu Formation of the Upper Proterozoic-Lower Cambrian Hyland Group underlies the property and is intruded by unfoliated mid-Cretaceous granitic stocks, dykes and sills of the Tombstone Plutonic Suite (TPS). Vein-type (both metasediment- and granite-hosted), skarn and replacement mineralization on the property is associated with the TPS intrusives.

Mapping, trenching and drilling by Kennecott identified numerous structurally controlled metasediment-hosted zones of mineralization within an east-west 3.5 km by 1.4 km > 40 ppb, gold soil anomaly. In 1997, a 13 hole 1052 m reverse circulation drill program tested the gold soil anomaly with the two best holes returning weighted averages of 0.48 g/t gold over 29 m (RC97-4) and 0.41 g/t gold over 61 m (RC97-11). In 1998, a seven hole 1268 m diamond drill program by La Teko tested targets defined using a combination of soil and rock gold anomalies, geological structures and chargeability and resistivity anomalies. Results included intersections of 1.04 g/t gold over 14.9 m, 1.07 g/t gold over 12.1 m, and 3.67 g/t gold over 7.7 m.

RÉSUMÉ

La Teko Resources ltée a acquis la propriété Scheelite Dome de Kennecott Canada Exploration inc. en 1998. Kennecott explorait cette propriété, située au centre du Yukon, depuis 1994. Le substrat rocheux, très déformé sur la propriété, appartient à la formation d'Yusezyu du groupe de Hyland qui date du Protérozoïque au Cambrien inférieur et qui est pénétrée par des stocks, des dykes et des filons- couches granitiques non feuilletés du Crétacé moyen de la suite plutonique de Tombstone (SPT). La propriété est charactérisée par des indices minéralisés associés aux roches intrusives de la SPT tels que les skarns, les indices de type filonien (recoupant les roches métasédimentaires ainsi que les roches granitiques) ainsi que la minéralisation de remplacement.

Les travaux de cartographie, de creusage de tranchées et de forage exécutés par Kennecott ont permis d'identifier de nombreuses zones minéralisées au sein d'une anomalie de sols de 3,5 sur 1,4 km, d'orientation est-ouest et renfermant plus de 40 parties par 10° d'or. La minéralisation est régie par des facteurs structuraux et est encaissée dans les roches métasédimentaires. En 1997, on a exécuté un programme de 13 sondages à circulation inverse totalisant 1052 m afin d'éprouver l'anomalie et ces trous ont recoupé des teneurs moyennes pondérées de 0,48 g/t d'or sur 29 m (RC97-4) et de 0,41 g/t d'or sur 61 m (RC97-11). En 1998, La Teko a exécuté un programme de forages au diamant dans le cadre duquel 7 forages totalisant 1268 m ont permis d'éprouver des cibles définies d'après des anomalies de sol et de roches, des structures géologiques et des anomalies de chargeabilité et de résistivité. Les résultats comprennent, entre autres, des recoupements de 1,04 g/t d'or sur 14,9 m, de 1,07 g/t d'or sur 12,1 m, et de 3,67 g/t d'or sur 7,7 m.

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INTRODUCTION

The Scheelite Dome gold project (Yukon Minfile 115P 003) is located near Mayo in central Yukon (Fig. 1). La Teko Resources Ltd. ("La Teko") has an option to earn a majority interest in the property from Kennecott Canada Exploration Inc. ("Kennecott") through fulfilling certain obligations.

The exploration target on the property is a metasediment-hosted gold deposit genetically related to Tombstone Plutonic Suite (TPS) granitic intrusions. Mineralization identified to date lies largely within a 3.5 km by 1.4 km, > 40 ppb gold-in-soil anomaly defined by Kennecott in 1996 (Fig. 1). The area has good road access and excellent exploration potential both within the large soil anomaly and elsewhere on the property.

PROPERTY HISTORY

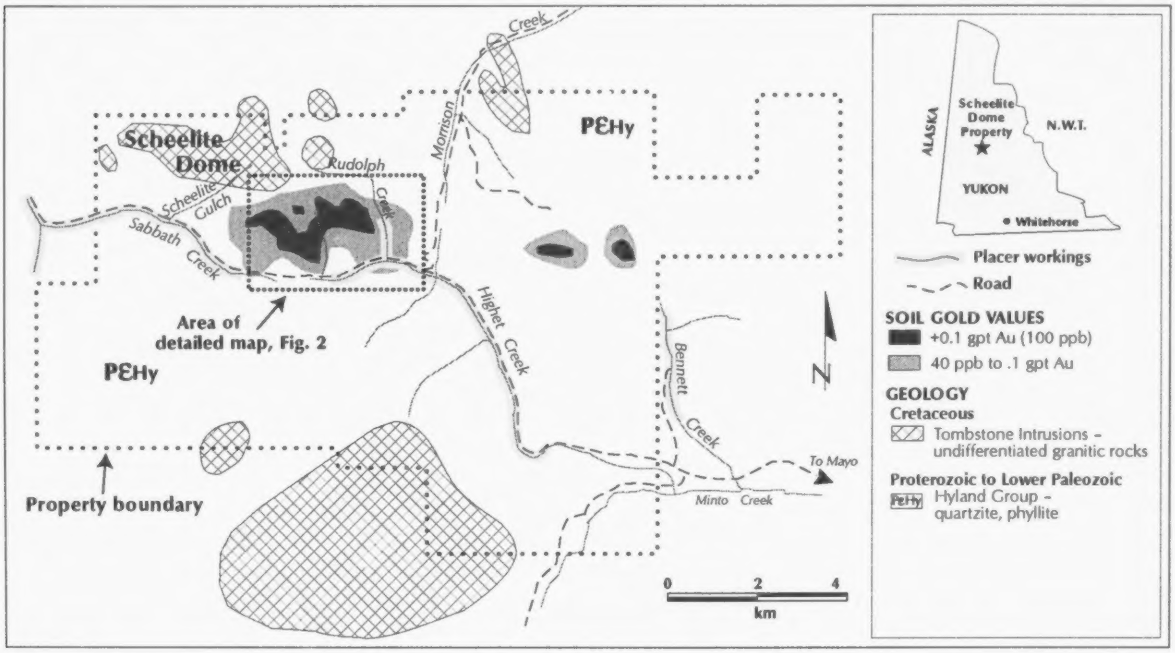
Placer gold was first discovered in this area in 1884 and placer mining continues to the present day (Kreft, 1993). Although the first lode claims were staked in 1916 (Yukon Minfile) the property has not seen any hard rock mineral production to date. The area has been re-staked several times since by Yukon prospectors and a number of mineral exploration companies.

Mr. Rudy Riepe staked the Gant and Ade claims, which form part of the current property, in 1986 and 1987, and optioned them in 1991 to H6000 Holdings Ltd. ("H6000") who had also staked a large block of surrounding claims. Exploration staff of H6000 were the discoverers of the Fort Knox gold deposit located near Fairbanks, Alaska and the Dublin Gulch gold deposit located 35 km to the northeast of Scheelite Dome. Both deposits are hosted by intrusions now included within the TPS (Poulsen et al., 1997). H6000 explored the Scheelite Dome and Minto Lake stocks for Fort Knox-type deposits with soil geochemical surveys, geological mapping and trenching. Results of this work were discouraging (Kajszo, 1992).

In 1994, Kennecott staked 60 claims in the area as part of a regional reconnaissance program. Soil and stream sediment sampling, geological mapping and prospecting indicated widespread zones of metasediment-hosted auriferous quartz-arsenopyrite mineralization. Additional claims were staked as the H6000 claims expired and in 1995 the Gant and Ade claims were optioned to Kennecott.

In 1995 and 1996, Kennecott conducted further soil sampling, excavated 19 trenches totalling 1 linear km in length, flew a 1275 line-km DIGHEM V helicopter electromagnetic, magnetic and VLF survey over the entire property and produced 5 m contour orthophoto maps from contracted aerial photography. An 8-hole diamond drilling program totalling 1035 m tested mineralized metasedimentary exposures in Highet Creek.

During 1997, a total of 9 km of roads were constructed to access the large gold-in-soil anomaly which was then tested with 13 reverse circulation drill (RVC) holes totalling 1052 m and



Creek
Scheelite Dome
Rudolph
Creek
Morrison
PЄHy
Scheelite Gulch
Sabbath Creek
Area of detailed map, Fig. 2
PЄHy
Highet Creek
Bennett Creek
To Mayo
Minto Creek
Property boundary
N
0 2 4
km
ALASKA
Scheelite Dome Property
N.W.T.
YUKON
Whitehorse
Placer workings
Road
SOIL GOLD VALUES
+0.1 gpt Au (100 ppb)
40 ppb to .1 gpt Au
GEOLOGY
Cretaceous
Tombstone Intrusions - undifferentiated granitic rocks
Proterozoic to Lower Paleozoic
PЄHy Hyland Group - quartzite, phyllite

Figure 1. Scheelite Dome property, geology and geochemistry.

eight excavator trenches totalling 1.7 linear km. The intensely fractured rock caused drilling problems and resulted in several holes being abandoned short of their target depth.

In 1998, La Teko optioned the property from Kennecott and conducted a 12.4 km induced polarization program followed by seven diamond drill holes totalling 1268 m. The drilling tested targets defined using a combination of features, including soil and rock gold anomalies, geological structures, and chargeability and resistivity anomalies. The results of this program are discussed below.

PROPERTY GEOLOGY

The property is underlain by the Yusezyu Formation, a siliciclastic unit of the Upper Proterozoic-Lower Cambrian Hyland Group (Murphy, 1997). The metasedimentary rocks include strongly foliated muscovite-chlorite phyllites, quartzofeldspathic and micaceous psammites ("quartzites"), and gritty psammites that locally form massive outcrops. Rare marble and calc-silicate layers are best developed in the northwest of the property in the vicinity of the Cominco Zone, located on the north side of the Scheelite Dome Stock, although pods and boudins of marble and limy psammite can be found throughout the property.

The property is located on the south-dipping limb of the southwesterly striking McQuesten Antiform within the Tombstone Strain Zone (Murphy, 1997). This package of rocks lies above the northeasterly vergent Tombstone Thrust. Fold and thrust deformation is believed to have occurred in Late Jurassic or Early Cretaceous times. A strong, northeasterly striking, moderately southeast dipping foliation affects the metasedimentary rocks and is the most prominent ductile fabric on the property. Small-scale isoclinal folds and crenulations are common.

The regional foliation is crosscut by three sets of moderately to steeply dipping fault and joint structures that strike east-west, northwest-southeast and north-south, respectively. The east-west and northwest-southeast structures host mineralization and therefore have received the most attention. The north-south structures are only rarely mineralized, have normal down-to-the-west displacement and appear to truncate and offset east-west structures. All of the structures form topographic lineaments.

The above structures were formed either during development of the McQuesten Antiform or as a result of faulting accompanying igneous emplacement. Alternatively, the structures may be extensional features related to a short-lived period of regional north-south extension coeval with Tombstone suite magmatism (Goldfarb, 1997).

Following Jura-Cretaceous deformation, the Yusezyu Formation was intruded by metaluminous and reduced I-type granitic intrusions of the 94-90 Ma TPS. The three stocks on the property, at Scheelite Dome, Morrison Creek and Minto Creek, have been dated at 91.2 ± -0.9 Ma, 92.5 ± -2.5 Ma and 92.2 ± 0.3 Ma, respectively (Murphy, 1997). The undated Minto Lake Stock lies to the south. All four stocks are massive, salt and pepper gray, medium grained quartz-, biotite- and hornblende-bearing granite with local feldspar megacrysts. Contact metamorphic aureoles containing biotite and andalusite surround the intrusions.

Thin, medium to fine grained felsic to intermediate dykes and sills, commonly quartz and/or feldspar porphyries, and narrow (< 1 m wide) lamprophyre dykes are probably part of the TPS. The dykes preferentially intrude the east-west structures.

MINERALIZATION

The property covers a coincident arsenic-gold-tungsten-antimony stream sediment anomaly identified by a GSC regional stream sediment sampling survey. This anomaly reflects the widespread occurrence of arsenopyrite and the more discrete occurrences of gold, scheelite and stibnite. The metallogenic signature also includes anomalous values for Ag, Bi, Mo, Pb and Te as do other examples of TPS intrusion-related mineralization.

The following four types of bedrock mineralization are recognized on the Scheelite Dome property:

1. structurally controlled metasediment-hosted quartz-sulphide veins;
2. skarn;
3. Fort Knox-type granite-hosted low sulphide veins;
4. replacement-type occurrences.

STRUCTURALLY CONTROLLED METASEDIMENT-HOSTED QUARTZ-SULPHIDE VEINS

Auriferous quartz veins are found throughout the property both within and outside the thermal aureole of the stocks. These veins are the main cause of the Scheelite Dome gold-in-soil anomaly. The veins commonly contain fine grained tourmaline as well as arsenopyrite, ± stibnite, ± galena, ± pyrite and they vary from breccia veins up to several metres in width occupying major fault zones, to thin quartz veinlets filling joint sets, locally close spaced and described as sheeted veins. Visible gold, found in a number of localities, usually occurs in association with arsenopyrite. Vein-wallrock contacts are sharp with narrow (commonly < 1 cm wide) selvages defined by bleaching, sulphidation, sericitization, silicification and tourmalinization. However, metasedimentary rocks crosscut by the veins are limonite-stained and are commonly weathered to depths of 10-15 m or more, implying the former presence of widely dispersed sulphides.

Two important vein sets have been identified: an east-west set that shares the orientation of the soil gold anomaly and a northwest-southeast set located within the soil anomaly in the Hawthorne Ridge area. The east-west vein set dips moderately to steeply north, and consists mainly of mm-thick veinlets filling joint sets and as rarer veins up to a metre wide. The veinlets and veins are commonly spaced 0.25 m to 1 m apart within discrete zones of fracturing and are preferentially developed within massive quartzite. Granitic dykes intruding the same structures have phyllic alteration, are auriferous and may contain up to several percent disseminated arsenopyrite and/or pyrite.

Gold mineralization intersected in drilling and trenches is typified by numerous zones (tens of metres wide) of low-grade (0.4-0.5 g/t) gold interspersed with zones of narrow higher grade mineralization. Rock samples from excavator trenches across east-west trending mineralization returned 0.66 g/t gold over 33 m and 0.43 g/t gold over 50 m from trenches approximately 750 m apart. Diamond drill holes 98-11 and 98-12, testing an east-west structure 500 m east of the trenches, returned 1.07 g/t gold over 12.1 m and 3.67 g/t gold over 7.7 m, respectively. A reverse-circulation drill hole (RC97-11), testing an east-west structure 1 km east of the trenches, returned 0.41 g/t gold over 61 m (with the drill hole abandoned at 61 m) while a diamond drill hole (98-10) returned 1.04 g/t gold over 14.9 m. Numerous high-grade grab samples of quartz veining, some with visible gold, returned greater than 10.0 g/t gold.

The northwest-southeast vein set dips to the northeast and is exemplified by the Hawthorne quartz-arsenopyrite-stibnite breccia vein. The vein is up to 1 m wide and pinches and swells within an 8 m wide zone of shearing, bleaching and sericite alteration. A parallel zone of jointing, veining and minor shearing approximately 8 m wide occurs in the footwall. The fault which the vein occupies, named the Hawthorne Structure (Fig. 2), is thought to extend for at least 3 km and is believed to cut and offset a portion of the Scheelite Dome intrusion. Rock chip samples collected across the Hawthorne Vein, including hanging-wall wallrock and the footwall zone, returned 0.53 g/t gold over 49 m, although individual chip samples returned up to 1.53 g/t gold over 0.40 m. The reverse circulation drill hole (RC97-3) that tested the possible eastward extension of the Hawthorne Vein returned 0.49 g/t gold over 19.8 m, with low arsenic and stibnite values. Diamond drill hole 98-14 tested this target and returned 1.04 g/t gold over 20 m. Reverse-circulation drill hole RC97-4, located approximately 250 m northeast of RC97-3, tested a northwest striking structure and returned a weighted average of 0.48 g/t gold over 29 m before it was abandoned after entering a fault zone.

Low-angle gouge (thrust?) zones that are locally auriferous have been identified in placer mining exposures along Highet Creek. At the Merle Pit Zone, a gently undulating 0.5-1.0 m wide arsenopyrite-bearing grey gouge zone crosscuts bleached and sericitized phyllitic quartzite and phyllite. A grab sample of the arsenopyrite-bearing gouge returned 7.5 g/t gold while chip samples over a strike length of 65 m and a width of 2.5 m returned a weighted average of 0.70 g/t gold.

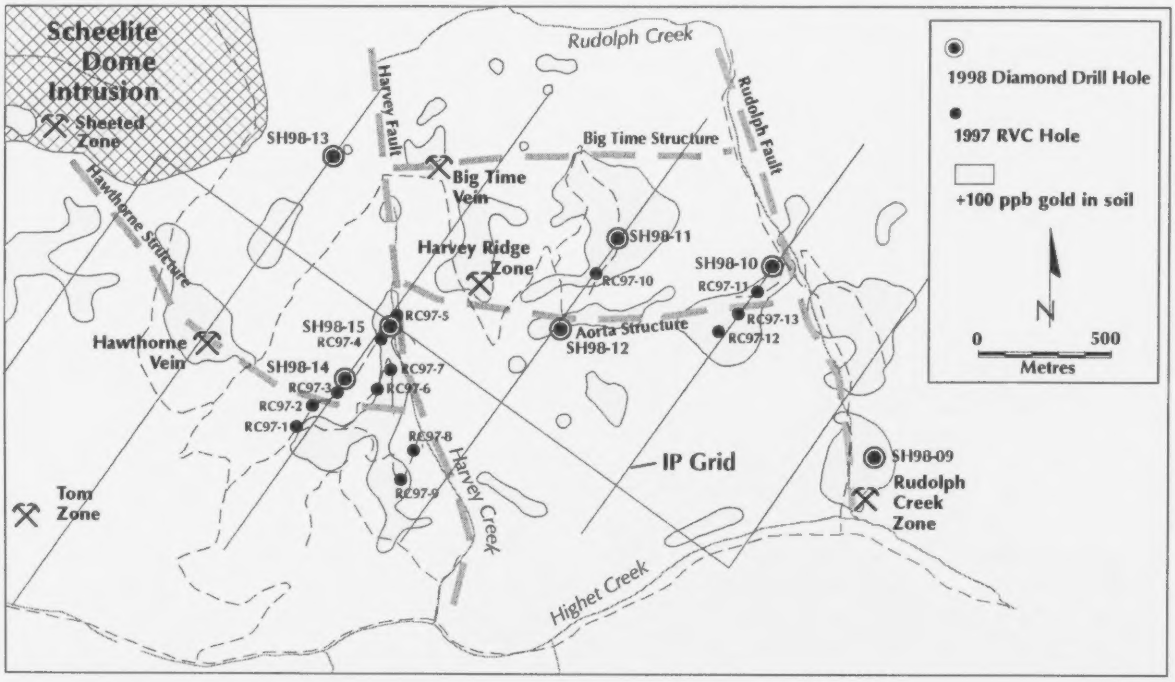

Scheelite Dome Intrusion
Sheeted Zone
Hawthorne Structure
Hawthorne Vein
Tom Zone
SH98-13
Harvey Fault
Rudolph Creek
Big Time Structure
Rudolph Fault
Big Time Vein
Harvey Ridge Zone
SH98-11
RC97-10
SH98-10
RC97-11
RC97-13
RC97-12
Aorta Structure
SH98-12
SH98-15
RC97-5
RC97-4
SH98-14
RC97-7
RC97-3
RC97-6
RC97-2
RC97-1
RC97-8
RC97-9
Harvey Creek
IP Grid
SH98-09
Rudolph Creek Zone
Highet Creek
1998 Diamond Drill Hole
1997 RVC Hole
+100 ppb gold in soil
N
0
500
Metres

Figure 2. Scheelite Dome property, 1998 drill holes.

SKARN

The Cominco Zone, located on the north side of the Scheelite Dome Stock, is an auriferous garnet-wollastonite-quartz-tremolite exoskarn with disseminations and clots of pyrrhotite, scheelite and chalcopyrite. The skarn is developed within a thin (< 10 m wide) band of massive marble along the intrusive contact. Cominco Ltd. trenched the zone in 1979 and tested it with three NQ-size diamond drill holes. The best intersection was 7.9 m of skarn averaging 0.95 g/t gold. Rock samples of pyrrhotite-bearing skarn collected by Kennecott returned between 0.68 g/t and 5.72 g/t gold, while sulphide-poor skarn returned < 0.74 g/t gold. The economic potential of the skarn appears to be low as the zone is well exposed and skarn widths are narrow at surface.

FORT KNOX-TYPE GRANITE-HOSTED LOW SULPHIDE VEINS

The Sheeted Zone (Fig. 2) is a small zone (250 m by 150 m) of quartz-feldspar-muscovite-scheelite-tourmaline stockwork near the head of Scheelite Gulch. The zone may be the northwest extension of the Hawthorne Structure. The veins which are similar in appearance to auriferous veins at the Fort Knox and Dublin Gulch gold deposits, are generally barren of gold although rare mineralized grab samples collected by H6000 returned up to 24.61 g/t gold (Kajszo, 1992). Three phases of veining are present, each with narrow (< 1 cm) selvages of sericitization, silicification and bleaching. Early thin milky white feldspar-quartz veinlets are crosscut by white to light grey quartz veinlets with minor feldspar which in turn are crosscut by white to grey quartz veinlets. The last two vein sets contain variable but generally minor arsenopyrite.

REPLACEMENT TYPE

Significant replacement mineralization has been located in Highet Creek, Harvey Creek and in the Tom Zone and lesser amounts of replacement mineralization are common elsewhere on the property. It is commonly restricted to fine to medium grained meta-quartzite containing minor amounts of calcite. Mineralization consists of disseminated (frequently > 1%) to semi-massive arsenopyrite, commonly as stubby euhedral crystals, in discontinuous foliaform bands < 10 cm thick. Such mineralization is found adjacent to steep to moderately dipping gouge zones and adjacent to narrow (< 2 cm wide) steeply dipping quartz-filled joints with silicified, seriticized and bleached selvages.

With the exception of the Tom Zone, gold geochemical results from these zones are disappointing although arsenic values frequently exceed the detection limit of 10,000 ppm. Interestingly, one of the better zones intersected in a diamond drill hole in Highet Creek returned 1.20 g/t gold over 4.4 m with arsenic values < 1000 ppm. Rock samples from a replaced marble unit in the Tom Zone returned values up to 11.76 g/t gold, > 10,000 ppm arsenic, 288 ppm bismuth and 2120 ppm tungsten over 0.6 m.

As mineralized quartz veins crosscut both the foliated metasediments and massive unfoliated granites, the majority of mineralization formed following intrusion emplacement. Fluid inclusions from crosscutting quartz veins collected from both the Scheelite Dome Stock and the metasedimentary rocks in Highet Creek are of low salinity (0 to 4 wt.% NaCl equivalent), CO_2-rich and have homogenization temperatures between 260 and 350°C (Pierce,1996; T. Baker, pers comm., 1997). Pierce (1996) concluded that the fluids were a mixture of magmatic and meteoric waters. No correlation between fluid inclusion temperature, salinity and distance from the intrusion/hornfels zone was apparent.

GEOPHYSICS

Magnetic contrast over the property is less than 200 nT. Most of the known mineralized areas lie within magnetic and resistivity lows, including the Heon Grid, Bleiler and Merle zones, all located east of Morrison Creek, and parts of the Hawthorne and Harvey Zones. Electromagnetic anomalies are frequently coincident with fault structures and lithological units and contacts.

A 12.4 line-km induced polarization survey was completed in 1998. The surveys were conducted in the time domain with a dipole-dipole array and a dipole separation of 50 m. Several chargeability and resistivity anomalies at depth correlate with structures identified at surface within areas of strong gold in soil anomalies.

DIAMOND DRILLING (1998)

In 1998, La Teko conducted a seven-hole reconnaissance diamond drilling program. A total of 1268 m of drilling was carried out on targets selected within a 2.1 km by 1.2 km area (Fig. 2). The drill holes ranged in length from 147 m to 216 m. Four holes were vertical and the balance were drilled at an azimuth of 215° and dips varying from 45º to 60º.

The drilling tested targets selected using a combination of controlling features, including gold-in-soil and rock anomalies, and chargeability and resistivity anomalies from the 1998 induced polarization survey. The targets were within a strong east-west striking gold mineralized system as outlined by anomalous gold-in-soils and bedrock over an area 4 km by 1.5 km.

Each of the drill holes intersected primarily quartzite and phyllite metasedimentary units with minor dykes. Within the drilling numerous sections were variably silicified and contained sulphide mineralization, including arsenopyrite, pyrite, pyrrhotite and stibnite (see Mineralization, Metasediment-hosted veins). Crosscutting quartz veins also occurred in various sections.

The drill hole results are summarized in the following table:

Drill hole	From *metres*	To *metres*	Length *metres*	Gold *g/tonne*
98-09	25.2	33.6	8.4	0.829
	50.0	52.0	2.0	0.751
	58.0	61.0	3.0	0.712
98-10	80.0	94.9	14.9	1.043
	90.9	93.9	3.0	2.620
98-11	99.8	111.9	12.1	1.073
	170.5	*171.3	0.8	1.650
98-12	16.3	24.0	7.7	3.668
98-14	65.6	85.6	20.0	1.037

* End of hole

True widths cannot be calculated until further drilling is completed. Two holes did not have any intercepts greater than 1.0 g/t gold. All holes, including these two, had numerous intercepts with gold greater than 100 ppb.

CONCLUSIONS

Mineralization is found over a large area on the Scheelite Dome property. The most significant mineralization explored to date occurs as quartz-sulphide veins within discrete structures that crosscut metasediments. Replacement style mineralization is of secondary importance. East-west zones of weakness are occupied by dykes and, following instrusion, served as channelways for gold-bearing fluids, developing quartz-sulphide veins. These structures are crosscut and truncated by unmineralized north-south faults. Blocks downdropped or uplifted by these later faults may juxtapose different structural levels and styles of mineralization.

Consideration will be given in the next phase of work to include the following elements in search of a structurally controlled bulk mineable gold deposit:

- step-out drilling on mineralized zones discovered this year;
- drill test other similar targets in the immediate area of the successful 1998 drill program;
- drill test additional targets with geological, geochemical and geophysical anomalies;
- conduct a more detailed induced polarization survey, a technique which successfully highlighted targets within the larger gold anomaly;
- further develop other geochemically anomalous areas on the 114 square km outside of the initial drill-tested area of 2.5 square km.

ACKNOWLEDGEMENTS

We thank La Teko and Kennecott for permission to publish this information. Tim Baker provided useful discussions of fluid inclusion results from samples he collected. We are particularly indebted to Kennecott staff and contractors who have worked on the property from 1994 to 1997, and to the staff and contractors of Equity Engineering Ltd. whose excellent work contributed greatly to the success of the 1998 program. Reviews and edits by Charlie Roots and Diane Emond improved the manuscript.

REFERENCES

Goldfarb, R.J., 1997. Metallogenic evolution of Alaska. *In:* Mineral Deposits of Alaska, Economic Geology, Monograph No. 9, p 4-34.

Kajszo, J., 1992. Assessment report on the Che, Hig and Mex claims; H6000 Holdings Ltd. Mineral Resources Directorate, Yukon, Indian and Northern Affairs Canada, Assessment Report #93052.

Kreft, B., 1993. Placer mining and exploration compilation (NTS 105M and 115P). Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, Open File 1993-10 (G).

Hornbrook, E.H.W. and Friske, P.W.B., 1988. Regional stream sediment and water geochemical data, central Yukon (115P, part of 105M). Geological Survey of Canada, Open File 1650.

Murphy, D. C, 1997. Geology of the McQuesten River region, northern McQuesten and Mayo map areas, Yukon Territory (115P/14,15,16; 105M/13,14). Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, Bulletin 6, 122 p.

Pierce, T., 1996. A study of mineralization and quartz veining in the Scheelite Dome intrusion and surrounding country rock. B.Sc. Honours Thesis, University of Victoria, British Columbia.

Poulsen, K.H., Mortensen, J.K. and Murphy, D.C. 1997. Styles of intrusion-related gold mineralization in the Dawson-Mayo area, Yukon Territory. *In:* Current Research 1997-A, Geological Survey of Canada, p. 1-10.

Yukon Minfile. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada. Also available from Hyperborean Productions, Whitehorse, Yukon.

Geology and mineralization of the Len intrusive-hosted gold prospect, McQuesten area, Yukon

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Keyser, H.J., 1999. Geology and mineralization of the Len intrusive-hosted gold prospect, McQuesten area, Yukon. *In:* Yukon Exploration and Geology 1998, C.F. Roots and D.S. Emond (eds.), Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 249-253.

ABSTRACT

The Len porphyry gold prospect is located 47 km north of Mayo, Yukon, in the Tombstone Suite intrusive belt. The area was explored as a Keno Hill-style silver prospect in the 1960s and 1970s. An arsenic-in-soil anomaly first identified in 1980 was followed up by soil geochemistry and excavator trenching in 1996. Multiple sheeted quartz-sulphide veins hosted in a previously unmapped granodiorite stock were discovered during the trenching program. A six-hole program of diamond drilling in 1997 encountered grades ranging up to 2.22 g/t gold across 18.6 m, and showed that gold mineralization is dominantly within, but not restricted to, the intrusive stock.

RÉSUMÉ

La zone d'intérêt pour l'or Len est située à 47 kilomètres au nord de Mayo (Yukon) dans la zone intrusive de la suite de Tombstone. La région a été explorée à titre de zone d'intérêt pour l'argent de type Keno Hill pendant les années 60 et 70. La première observation d'une concentration élevée d'arsenic dans le sol en 1980 a été suivie d'analyses géochimiques des sols et de l'excavation de tranchées en 1996. De multiples filons de quartz avec sulfures encaissés dans un stock granodioritique jusqu'ici non cartographié ont été découverts dans le cadre du programme d'excavation de tranchées. Un programme de six forages au diamant exécuté en 1997 a permis de recouper des teneurs atteignant jusqu'à 2,22 g/T d'or sur 18,6 mètres et a montré que la minéralisation en or se concentre principalement, mais non exclusivement, dans le stock intrusif.

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INTRODUCTION

The Len gold prospect is located at Skate Creek, 47 km north of Mayo, Yukon and 8 km east of New Millenium Mining Ltd.'s Dublin Gulch gold deposit (Fig. 1). Bedrock gold mineralization was discovered in 1996 by trenching zones of anomalous gold, arsenic, and antimony values in an overburden-covered, thickly forested area.

HISTORY

The earliest recorded bedrock mineral exploration in the area of the Len prospect was in 1965, when United Keno Hill Mines Limited explored for the source of anomalous stream sediments identified by the Geological Survey of Canada during Operation Keno (Van Tassell, 1970). This work culminated in the discovery of a Keno Hill-style argentiferous galena-siderite vein (Yukon Minfile 106D 020, Skate). During the period 1969 to 1974, the vein was explored by trenching and diamond drilling. In 1978, Gordon and Janet Dickson acquired the ground. Soil geochemistry completed in 1980 identified a large arsenic anomaly (McAtee, 1980) centred one km to the east of the galena-siderite vein. These samples were not analyzed for gold. Balaclava Mines Inc. and Panamex Resources Inc. optioned the ground in 1996 to explore for bedrock gold mineralization associated with the previously identified arsenic anomaly. Soil geochemistry, geological mapping, geophysics, and trenching were completed in 1996, followed by 500 m of diamond drilling in 1997.

GEOLOGY

The Len prospect is located in an intrusive belt known as the Tombstone Plutonic Suite. The oldest rocks in the area are schist and limestone of the Upper Proterozoic to Lower Cambrian Hyland Group which have been thrust over variably deformed Keno Hill quartzite (Boyle and Gleeson, 1980). Regional scale geological mapping (Green, 1972) does not show intrusives in the area of the Len prospect. Detailed mapping of boulders and rock rubble in 1996 suggested that a 400 x 700 metre elliptical granodiorite stock (Fig. 2) was centred 1 km east of the previously identified galena-siderite vein. The stock locally contains disseminated arsenopyrite and rare tourmaline, and is variably silicified and sericitized, particularly near the southern margin. An east-west fracture system at the southern margin of the granodiorite stock has recessive weathering and forms an indistinct break in slope. Trench exposures suggest that the southern intrusive contact of the stock dips gently to the south and may coincide with a thrust fault.

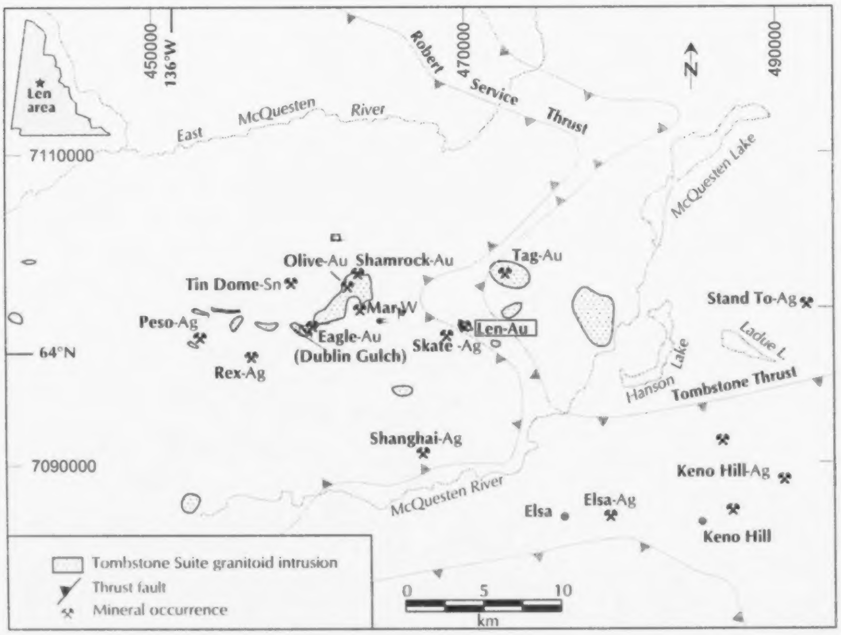
Len area
450000
136°W
470000
490000
N
Robert Service Thrust
East McQuesten River
7110000
McQuesten Lake
Olive-Au
Shamrock-Au
Tag-Au
Tin Dome-Sn
Mar-W
Stand To-Ag
Peso-Ag
Eagle-Au
(Dublin Gulch)
Len-Au
Skate -Ag
Ladue L.
64°N
Rex-Ag
Hanson Lake
Tombstone Thrust
Shanghai-Ag
7090000
Keno Hill-Ag
McQuesten River
Elsa
Elsa-Ag
Keno Hill
Tombstone Suite granitoid intrusion
Thrust fault
Mineral occurrence
0
5
10
km

Figure 1. Granitoid intrusions and mineral occurrences – Len area. Thrust faults modified from Green (1971) and C.F. Roots (pers. comm., 1998).

GEOCHEMISTRY

Soil geochemistry was completed in 1996 to determine whether gold was present in the area of the arsenic anomaly identified in 1980. The 1996 samples were sieved to -150 mesh (Tyler screen) and anomalous thresholds were established at 30 ppb gold, 200 ppm arsenic, and 30 ppm antimony. A 500 x 1600 metre gold-arsenic-antimony anomaly was identified closely coincident with the granodiorite stock as defined by the distribution of granodiorite boulders and rubble in soil. Bismuth, silver, and lead are variably anomalous. Stream sediments collected one km downstream of subsequently exposed mineralization and sieved to -230 mesh are anomalous in gold (up to 250 ppb), arsenic, and antimony.

MINERALIZATION

In 1996, detailed examination of lithic material recovered from hand-dug pits within the geochemically anomalous area identified rare angular quartz-arsenopyrite pebbles and cobbles carrying anomalous, but sub-ore grade, gold values in soil and thin glacial alluvium. Subsequent excavator trenching exposed multiple, structurally controlled, sheeted quartz-sulphide-carbonate veins striking approximately parallel with the south margin of the granodiorite stock. Veins range in size from one millimetre to two metres. They dip steeply to the north, and have been traced along a strike length of 600 m. Arsenopyrite is the dominant sulphide, with lesser amounts of galena, sphalerite, pyrite, stibnite, and bismuthinite. Fine grained arsenopyrite and stibnite coat some fracture surfaces, without quartz. Sulphide minerals are strongly oxidized to a depth of approximately 10 m, resulting in locally gossanous soil and dispersed metal values.

Trench samples ranging up to 22.2 g/t gold across 3.0 m and another zone of 4.4 g/t gold across 8.0 m led to the decision to drill the prospect. A total of six inclined diamond drill holes (Fig. 3) were completed in 1997, which tested the mineralization along a strike length of 400 m. All of the holes intersected gold mineralization grading in excess of 4 g/t across variable widths. Two of the most significant intervals (all apparent widths) are 2.22 g/t gold across 18.6 m (including 7.06 g/t across 4.3 m) in Hole 97-01, and 1.27 g/t gold across 32.0 m (including 7.37 g/t across 3.4 m) in Hole 97-03. Gold mineralization is not restricted to the granodiorite. The last and easternmost hole (97-06) of the

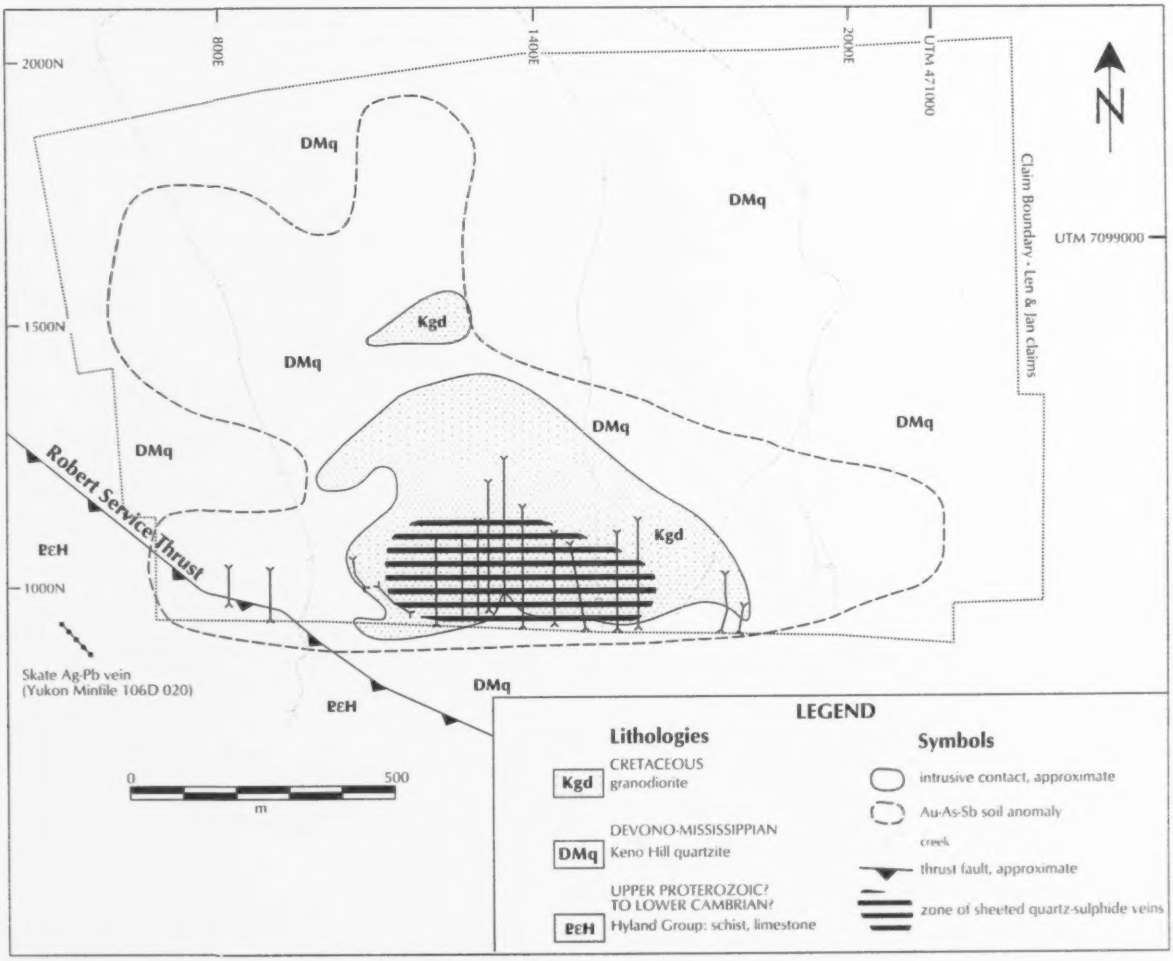
2000N
800E
1400E
2000E
UTM 471000
N
Claim Boundary - Len & Jan claims
UTM 7099000
1500N
1000N
DMq
Kgd
ЄЄH
Robert Service Thrust
Skate Ag-Pb vein
(Yukon Minfile 106D 020)
0
500
m
LEGEND
Lithologies
Kgd
CRETACEOUS
granodiorite
DMq
DEVONO-MISSISSIPPIAN
Keno Hill quartzite
ЄЄH
UPPER PROTEROZOIC?
TO LOWER CAMBRIAN?
Hyland Group: schist, limestone
Symbols
intrusive contact, approximate
Au-As-Sb soil anomaly
creek
thrust fault, approximate
zone of sheeted quartz-sulphide veins

Figure 2. *Simplified geology and geochemistry of Len prospect.*

1997 drilling program (Fig. 4) encountered fractured and veined limonitic quartzite below trench exposures of similarly mineralized granodiorite. In addition to gold, mineralized intervals are variably anomalous in arsenic, silver, lead, zinc, copper, antimony, cadmium, iron and bismuth.

DISCUSSION

Exploration work that culminated in the discovery of bedrock gold mineralization at the Len prospect in 1996 was based on study of the results of exploration programs carried out during the period 1965 to 1980. Even though the previous exploration target was silver-bearing vein-type mineralization in Keno Hill quartzite, data filed by previous operators were instrumental in the success of the 1996-1997 work. The large arsenic-in-soil anomaly and granodiorite boulders were re-evaluated as potential indicators of porphyry-style gold mineralization, and allowed the current work to focus on a relatively small area. Nevertheless, mineralization at the Len prospect could have been identified earlier using detailed stream sediment geochemistry with multi-element analyses performed on fine fractions.

The 1996 soil geochemistry was carried out on a grid with sample spacings as detailed as 10 x 50 m, which led to specific sites where quartz-arsenopyrite fragments were first identified in hand-dug soil pits. Subsequent examination of the geochemical data shows that grid spacings of 25 x 200 m would have been sufficient to identify a large gold-arsenic-antimony soil anomaly. Anomalous values of antimony and bismuth in soil best defined the known zone of gold mineralization, more precisely than gold or other pathfinder elements.

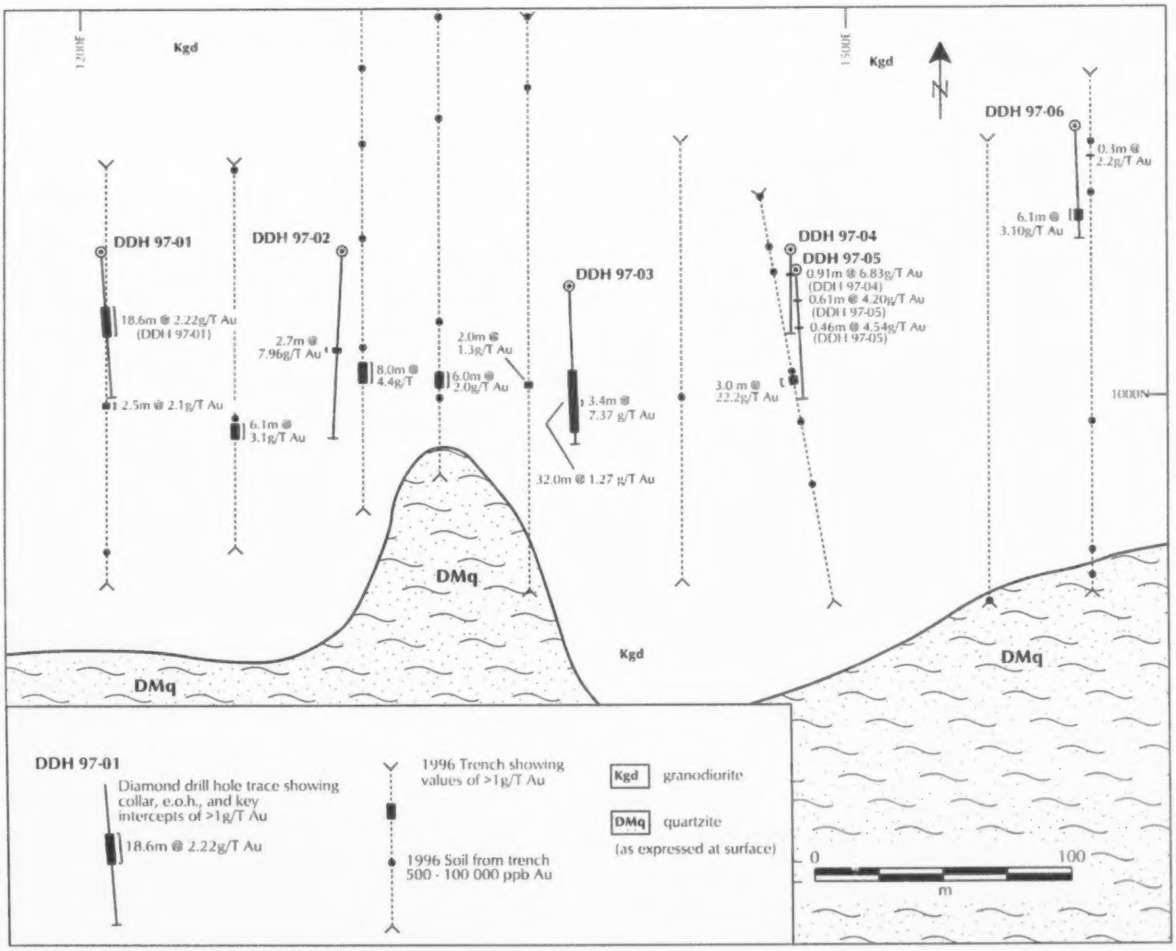
1200E
Kgd
1500E
Kgd
N
DDH 97-01
18.6m @ 2.22g/T Au (DDH 97-01)
2.5m @ 2.1g/T Au
6.1m @ 3.1g/T Au
DDH 97-02
2.7m @ 7.96g/T Au
8.0m @ 4.4g/T
2.0m @ 1.3g/T Au
6.0m @ 2.0g/T Au
DDH 97-03
3.4m @ 7.37 g/T Au
32.0m @ 1.27 g/T Au
DDH 97-04
DDH 97-05
0.91m @ 6.83g/T Au (DDH 97-04)
0.61m @ 4.20g/T Au (DDH 97-05)
0.46m @ 4.54g/T Au (DDH 97-05)
3.0 m @ 22.2g/T Au
DDH 97-06
0.3m @ 2.2g/T Au
6.1m @ 3.10g/T Au
1000N
DMq
Kgd
DMq
DMq
DDH 97-01
Diamond drill hole trace showing collar, e.o.h., and key intercepts of >1g/T Au
18.6m @ 2.22g/T Au
1996 Trench showing values of >1g/T Au
1996 Soil from trench 500 - 100 000 ppb Au
Kgd granodiorite
DMq quartzite
(as expressed at surface)
0
100
m

Figure 3. *Len prospect trench and drill hole plan.*

CONCLUSIONS

The Len prospect is a new Tombstone Suite intrusive hosted gold occurrence similar to the Dublin Gulch and Fort Knox porphyry gold deposits. It was discovered in a completely overburden-covered area by a systematic exploration program. Work included mapping a previously unknown intrusive stock by defining granodiorite rubble in overburden, carrying out gold-arsenic-antimony soil geochemistry, excavator trenching and diamond drilling. Exploration to date has not defined any limits to the mineralized zone. While many known intrusive stocks in the Tombstone Suite intrusive belt have been explored for their gold potential with variable success, the discovery of the Len gold prospect in an overburden-covered area demonstrates the potential for many more unexposed and unexplored Tombstone Suite intrusives.

Figure 4. *Diamond drilling on Len property, in 1997.*

ACKNOWLEDGEMENTS

David Pass, Michael Glynn, Al Doherty, Ben Johnson and Hans Smit contributed to the understanding of the geology and mineralization of the Len prospect. Ken Galambos, Steve Dudka and Charlie Roots suggested improvements to the text and figures.

REFERENCES

Boyle, R.W. and C.F. Gleeson, 1980. The lithogeochemistry of the Keno Hill district, Yukon Territory. Geological Survey of Canada, Paper 77-31, 19 p.

Green, L.H., 1972. Geology of Nash Creek, Larsen Creek and Dawson map areas, Yukon Territory. Geological Survey of Canada, Memoir 364, 157 p.

McAtee, C.L., 1980. A geological report on the Len 1-32 claims of Tally Resources Inc. Mineral Resources Directorate, Yukon, Indian and Northern Affairs Canada, Assessment Report 90813.

Van Tassell, R.E., 1970. Geological and Geochemical Report on the Erin 1-28 and 31-189 mineral claims inclusive. Mineral Resources Directorate, Yukon, Indian and Northern Affairs Canada, Assessment Report 60724.

Yukon Minfile. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada. Also available from Hyperborean Productions, Whitehorse, Yukon.

A new mineral occurrence in Yukon-Tanana Terrane near Little Salmon Lake (105L/2), central Yukon

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Yukon Geology Program

Colpron, M., 1999. A new mineral occurrence in Yukon-Tanana Terrane near Little Salmon Lake (105L/2), central Yukon. *In:* Yukon Exploration and Geology 1998, C.F. Roots and D.S. Emond (eds.), Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 255-258.

ABSTRACT

A new occurrence of sulphide-bearing iron formation is reported from a roadcut of Yukon-Tanana Terrane rocks along the Robert Campbell Highway, near Little Salmon Lake. This new discovery confirms the high potential for volcanogenic massive sulphide deposits similar to those of the Finlayson Lake district in Yukon-Tanana Terrane southwest of Tintina Trench.

RÉSUMÉ

Un nouvel indice de formation de fer sulfurée a été découvert dans un affleurement du terrane de Yukon-Tanana le long de la route Robert Campbell, près du lac Little Salmon. Cette nouvelle découverte confirme le haut potentiel pour des gisements de sulfures massifs volcanogènes, comparables à ceux de la région de Finlayson Lake, au sein du terrane de Yukon-Tanana au sud-ouest du sillon de Tintina.

INTRODUCTION

A new sulphide occurrence anomalous in copper was discovered in southern Glenlyon map area (UTM Zone 8, 520416E, 6895423N; NTS 105L/2; Fig. 1) during geological reconnaissance along the Robert Campbell Highway, near Little Salmon Lake. Detailed studies along Little Salmon Lake (Oliver and Mortensen, 1998) and regional mapping along strike to the north (Colpron, this volume) have confirmed the correlation of a 30-50 km-wide, northwest-striking belt of metasedimentary, metavolcanic and metaplutonic rocks in the centre of Glenlyon map area within Yukon-Tanana Terrane (Fig. 1). Restoration of 450 km of dextral displacement along Tintina Fault positions strata in the Little Salmon Lake area south of Yukon-Tanana Terrane rocks in the Finlayson Lake district which contains numerous volcanic-hosted massive sulphide (VMS) deposits and occurrences (Hunt, 1997).

DESCRIPTION

The roadcut described here is on the north side of the Robert Campbell Highway, about 12 km west of Drury Creek (Fig. 1). It consists of white muscovite-quartz-feldspar augen schist (felsic metavolcanic rocks).

Sulphide mineralization (pyrite-chalcopyrite) occurs in two horizons of magnetite iron formation. One horizon (10-15 cm thick) is located about 30 m from the west end of the roadcut and consists of disseminated pyrite (~15%), magnetite (1-2%) and chalcopyrite (trace) in a foliated matrix of chlorite-epidote-muscovite-calcite-quartz-plagioclase[1]. Pyrite occurs as euhedral to subhedral grains up to 1 mm. Chalcopyrite is most commonly present as small inclusions (≤10 µm) within the pyrite but also occurs as interstitial grains in the matrix. Magnetite forms small (10-30 µm) elongated grains. Assay results representative of this horizon (98LS-1a) are presented in Table 1.

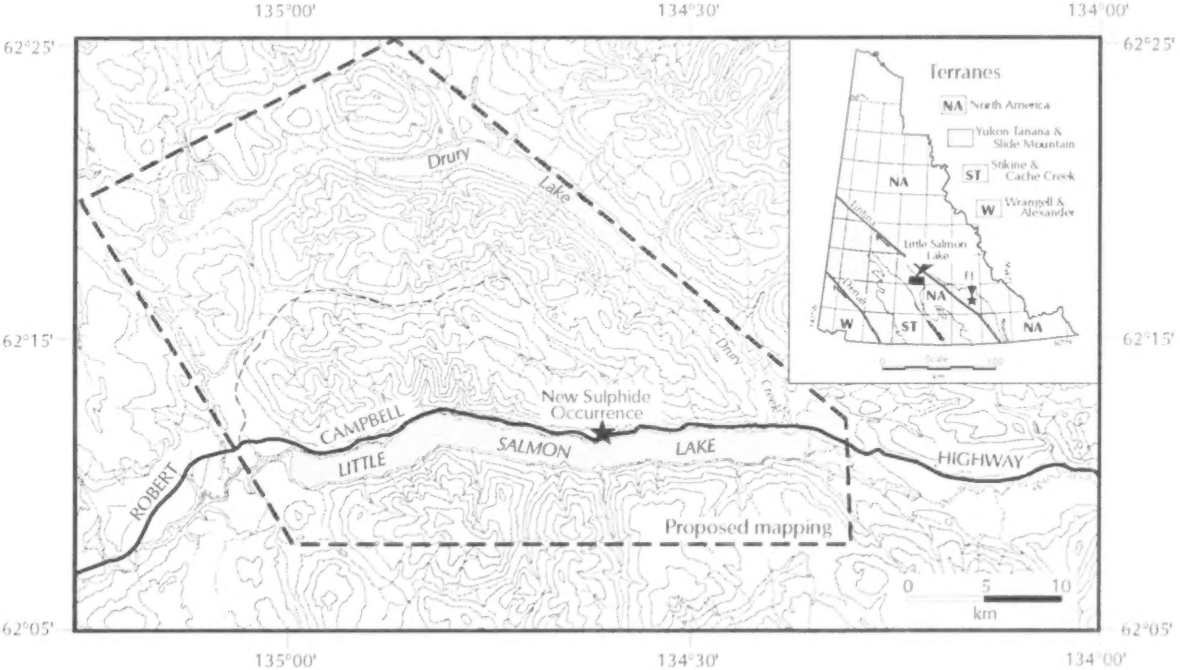
135°00'
134°30'
134°00'
62°25'
62°15'
62°05'
Drury
Lake
Drury
Creek
New Sulphide
Occurrence
ROBERT
CAMPBELL
HIGHWAY
LITTLE
SALMON
LAKE
Proposed mapping
0
5
10
km
Terranes
NA North America
Yukon Tanana & Slide Mountain
ST Stikine & Cache Creek
W Wrangell & Alexander
NA
Tintina
Little Salmon Lake
FL
Denali
W
ST
NA
NA

Figure 1. *Location of the new sulphide occurrence (star). Inset shows the Little Salmon Lake area with respect to distribution of Yukon-Tanana terrane in Yukon and the Finlayson Lake district (FL). Heavy dash line indicates area of proposed bedrock mapping as part of the Glenlyon project.*

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[1] Matrix minerals are listed in decreasing order of relative abundance.

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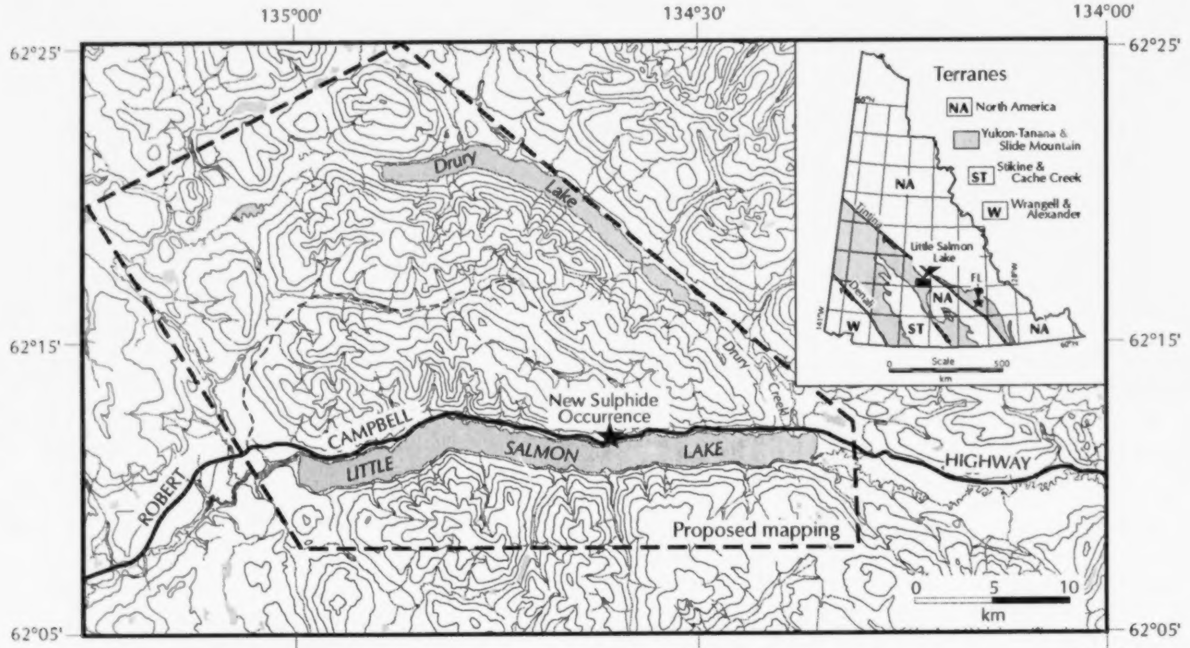
135°00'
134°30'
134°00'
62°25'
62°15'
62°05'
Drury
Lake
Drury
Creek
New Sulphide
Occurrence
CAMPBELL
LITTLE
SALMON
LAKE
HIGHWAY
ROBERT
Proposed mapping
0
5
10
km
Terranes
NA North America
Yukon-Tanana & Slide Mountain
ST Stikine & Cache Creek
W Wrangell & Alexander
NA
Tintina
Little Salmon Lake
FL
Denali
W
ST
NA
NA
141°W
Scale
0
500
km

Figure 1. Location of the new sulphide occurrence (star). Inset shows the Little Salmon Lake area with respect to distribution of Yukon-Tanana terrane in Yukon and the Finlayson Lake district (FL). Heavy dash line indicates area of proposed bedrock mapping as part of the Glenlyon project.

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[1] Matrix minerals are listed in decreasing order of relative abundance.

A second sulphide-bearing horizon (~50 cm thick) is present at the western end of the roadcut. It consists of semi-massive pyrite (~40%), magnetite (5-10%) and chalcopyrite (trace) in a medium-grained, weakly foliated matrix of chlorite-quartz-calcite-plagioclase (Fig. 2). Pyrite occurs as coarse subhedral grains up to 5 mm long. Anhedral grains of magnetite (10-50 µm) occur locally as inclusions in pyrite, but are more commonly present as interstitial grains within the chlorite matrix. As in the first horizon, chalcopyrite (≤20 µm) most commonly occurs as inclusions within the pyrite. Assay results from two samples from this horizon (98LS-1b, c) are presented in Table 1.

DISCUSSION

The discovery of a sulphide-bearing iron formation within a sequence of altered felsic metavolcanic rocks along the Robert Campbell Highway attests to the high potential for discovery of additional VMS deposits in Yukon-Tanana Terrane southwest of Tintina Trench. The Little Salmon Lake iron formation strongly resembles the iron formation which occupies a similar stratigraphic position as the Kudz Ze Kayah deposit in the Finlayson Lake district (Murphy and Piercey, this volume) and, therefore, constitutes a pathfinder for this type of deposit. No regional-scale geochemical anomaly is associated with this new occurrence, although weak northwest-trending (parallel to regional strike) anomalies in Co, Cu, Au, Pb and Ni occur on both sides of Little Salmon Lake (Friske and Hornbrook, 1989).

The stratigraphic and structural contexts of this new occurrence are largely unknown. Although a stratigraphic succession has been proposed for the eastern part of Little Salmon Lake (Oliver and Mortensen, 1998), the felsic metavolcanic rocks which host this new sulphide occurrence had not been identified. Also, based on the current understanding of the regional and local structures (Campbell, 1967; Oliver, 1996), it is unclear whether the two sulphide-bearing horizons identified in this roadcut constitute two distinct horizons or a single structurally repeated horizon. In order to resolve the stratigraphic and structural settings of this new sulphide occurrence, bedrock mapping of the area between Little Salmon and Drury lakes by the Yukon Geology Program has been proposed (Fig. 1). An additional objective of this study will be to determine whether the stratigraphic sequence established in the northwestern part of Glenlyon map area (Colpron, 1999, this volume) could be extended to Little Salmon Lake area.

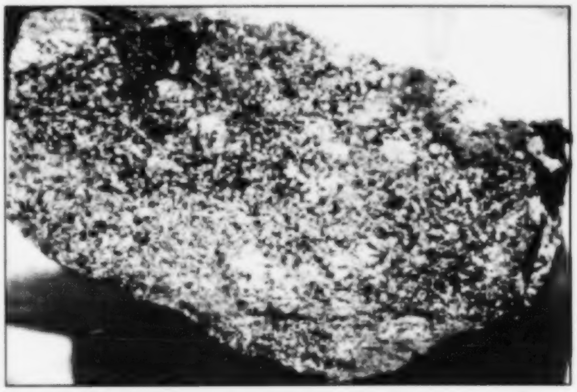

Figure 2. *Semi-massive sulphide mineralization (white grains) from iron formation at west end of roadcut (sample 98LS-1b). Sample is 8 x 14 cm.*

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REFERENCES

Campbell, R.B., 1967. Geology of Glenlyon map-area, Yukon Territory (105 L). Geological Survey of Canada, Memoir 352, 92 p.

Colpron, M., 1999 (this volume). Glenlyon project: Preliminary stratigraphy and structure of Yukon-Tanana Terrane, Little Kalzas Lake area, central Yukon (105L/13). *In:* Yukon Exploration and Geology 1998, C.F. Roots and D.S. Emond (eds.), Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 63-72.

Sample	Au ppb	Ag ppm	As ppm	Ba ppm	Cd ppm	Co ppm	Cr ppm	Cu ppm	Fe %	Mn ppm	Ni ppm	Pb ppm	Zn ppm	Comments
98LS-1a	10	0.8	10	40	0.5	31	61	606	10.30	960	51	30	76	disseminated Py-Cpy in 10-15 cm Mt Fe-fm
98LS-1b	< 5	1.4	18	< 10	< 0.5	43	55	573	> 15.00	1050	15	20	62	semi-massive Py-Cpy in 50 cm Mt Fe-fm
98LS-1c	< 5	1.4	10	< 10	< 0.5	67	57	531	> 15.00	1095	11	16	30	duplicate of 98LS-1b

Table 1. *Selected assay results from sulphide-bearing iron formations, Little Salmon Lake area. Analyses completed by Chemex Labs Ltd., North Vancouver, B.C. Au by fire assay; all other elements by ICP. Py: pyrite; Cpy: chalcopyrite; Mt Fe-fm: magnetite-bearing iron formation.*

Friske, P.W. and Hornbrook, E.H., 1989. National Geochemical Reconnaissance Stream Sediment and Water Geochemical Data, central Yukon (105K/W and 105L). Geological Survey of Canada, Open File 1961.

Hunt, J.A., 1997. Massive sulphide deposits in the Yukon-Tanana and adjacent terranes. *In:* Yukon Exploration and Geology 1996, Exploration and Geological Services Division, Yukon Indian and Northern Affairs Canada, p. 35-45.

Murphy, D. and Piercey, S.J., 1999 (this volume). Finlayson project: Geological evolution of Yukon-Tanana Terrane and its relationship to Campbell Range belt, northern Wolverine Lake map area, southeastern Yukon. *In:* Yukon Exploration and Geology 1998, C.F. Roots and D.S. Emond (eds.), Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 47-62.

Oliver, D.H., 1996. Structural, kinematic, and thermochronologic studies of the Teslin suture zone, south-central Yukon Territory. Unpublished Ph.D. thesis, Southern Methodist University, Dallas, Texas, 231 p.

Oliver, D.H. and Mortensen, J.K., 1998. Stratigraphic succession and U-Pb geochronology from the Teslin suture zone, south central Yukon. *In:* Yukon Exploration and Geology 1997, Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 69-75.